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GENERAL ELECTRIC Review

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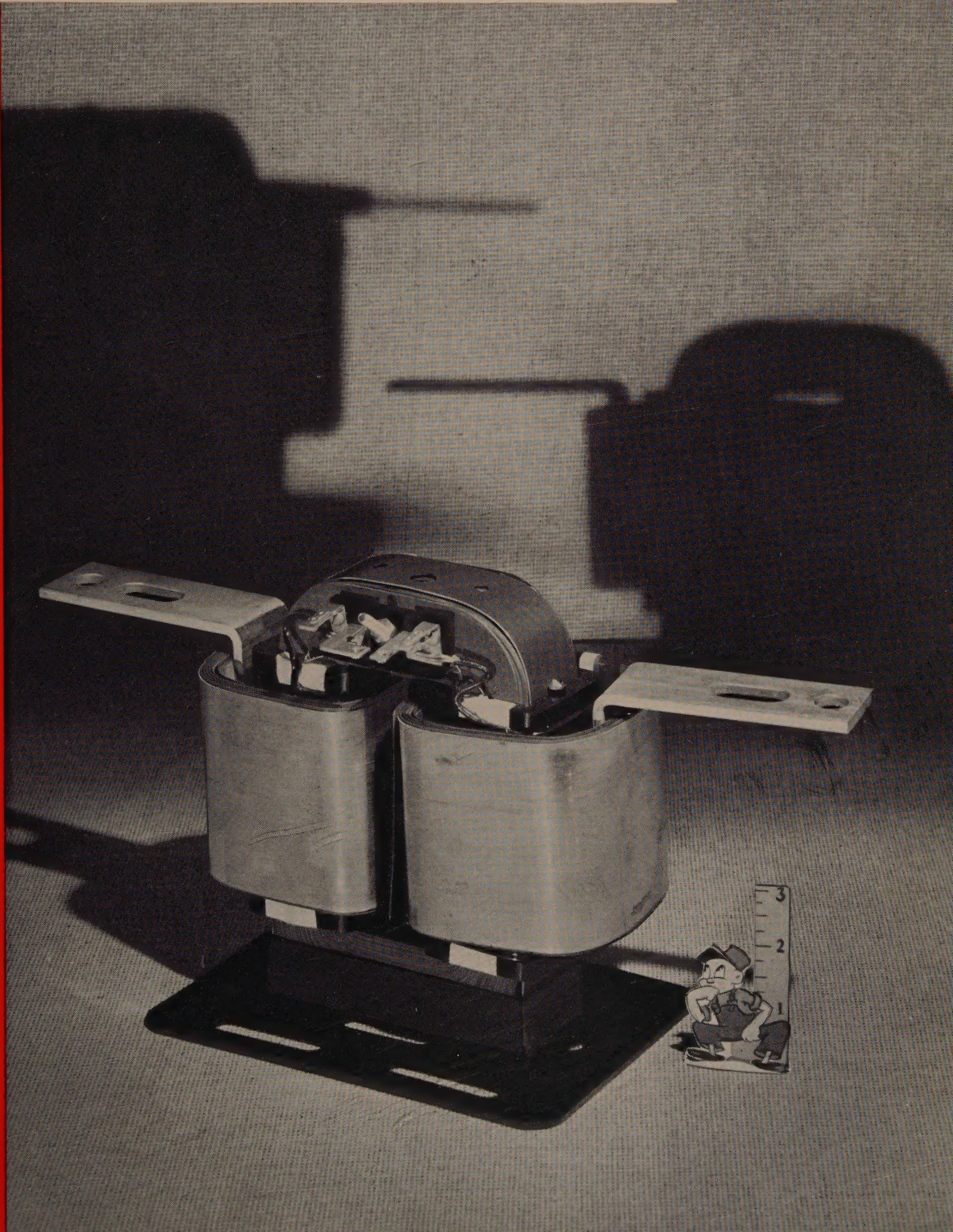

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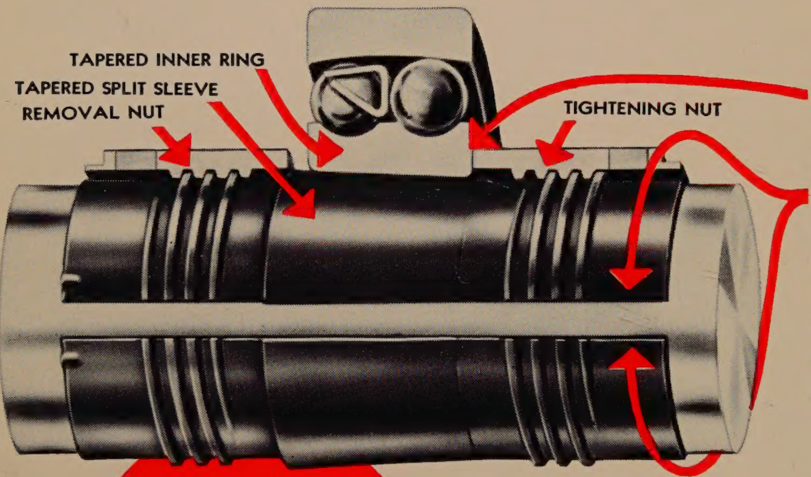

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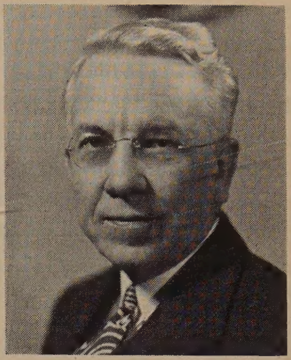
The Twenty-second Steinmetz Memorial Lecture

NATURAL RESOURCES AND HUMAN PROGRESS



By **DR. KIRTLEY F. MATHER**
Professor of Geology, Harvard University

IT is highly appropriate that this year the Steinmetz Memorial Lecture should deal with the relations between natural resources, industrial development, population growth, and human progress. Among the several motives that inspired Charles Proteus Steinmetz to devote his extraordinary abilities unceasingly to scientific research and technological development, high priority must be assigned to his deep-rooted desire to extend the utilization of the earth's resources for the welfare of mankind. The Steinmetz Memorial Foundation, under whose auspices I am speaking, is a fitting tribute to his superb achievements toward that commendable end. His name stands high on the list of noble men whose activities have led to the gratifying concept that ours is a world of potential abundance, a world in which every man may be efficient, well-nourished, comfortable, and happy.

As we stand here at the midpoint of the twentieth century, there are many, however, who raise grave doubts concerning the validity of that concept. Does not the rapid expansion of human populations raise demands for the materials essential for existence to levels beyond the capacity of the sources of supply? Is not the warning note sounded by Malthus at the start of the nineteenth century even more appropriate for us a hundred and fifty years later? Is potential abundance a myth rather than a fact? Such questions acquire incisive force as we contemplate the ravages of World War II and observe the miserable conditions surrounding the lives of half the human family in a world that has in our own lifetime become a single, somewhat crowded neighborhood.

MAN THE IMPLEMENT-MAKER

Man is the first and only implement-making creature in the long procession of the living that has left a partial record of its progress in the rocks of the geologic past. Various animals have been known to seize a stick or stone and employ it as an implement; but early man improved the shape of the pebble he picked up, the piece of wood he found in the forest, and the bones he selected from the skeletons of dead animals. Far back in the "stone age," he soon learned that certain kinds of rock could best be shaped to a cutting edge and fashioned into the most efficient tools or weapons. The aboriginal artisans of the Ohio valley found, for example, that the flinty limestones cropping out on the flanks of a ridge near Newark (Ohio) were especially suitable as sources of raw materials for the primitive manufacturing industry of their day. That local occurrence of what was then one of the most valuable mineral resources of North America determined the pattern of exploitation, processing and distribution of consumer goods that has persisted in all its essential characteristics to the present time.

Even in the days when men were merely food-gatherers, like almost all the other animals, they found themselves dependent upon locally concentrated mineral resources for the best spear points, arrowheads, and harpoon blades. Some of these distant ancestors of ours progressed to the stage of food-producing and it was their invention of the first agricultural machinery that opened a new epoch in the life of man. As man became the machine-maker he found himself increasingly dependent upon the unevenly distributed and locally concentrated resources of the earth. With the greater application of the scientific method since the beginning of the industrial revolution nearly two hundred years ago, that dependence has become ever more influential, farther reaching, and inescapable.

Labor-saving, power-driven machinery, mechanical devices in our homes and offices—in short, all the comforts of modern civilization—call for a constant supply of raw materials from mines and quarries, fields and forests. The efficiency and comfort available through the application of the results of scientific research to industry and commerce are gained only at the expense of nature's store of source materials. Each new advance in technology creates new needs for minerals and agricultural products.

THE RISING TIDE OF DEMANDS FOR MINERAL RESOURCES

The world as a whole has consumed more of its mineral stores since 1900 than in all the previous history of mankind. Petroleum production in the United States

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

did not amount to 100 million barrels per year until after that date. In the early 1920's it exceeded a half billion barrels per year, and fifteen years later it reached a billion barrels per year. In 1943 the rising curve of annual production crossed the one and a half billion barrel mark and in 1948 it reached two billion barrels. Iron ore was being mined in the United States at annual rates of only about 60 million tons in the early 1920's, whereas more than 100 million tons have been mined each year since 1942.

Similarly, the per capita consumption of mechanical energy is rapidly increasing. Most of the high-speed, labor-saving machinery of our technologic age is power driven. The United States consumes about three times as much energy per person at this time as it did fifty years ago. A little more than 52 percent of this energy is derived from coal, 44 percent from petroleum, and less than 4 percent from water power.

Mineral fuels and metalliferous ores are nonrenewable resources. They constitute nature's stored capital. As such natural resources are used, the stores are depleted, and eventually they will be exhausted. Water power and the agricultural resources derived from plants and animals are renewable. They constitute man's annual income. If wisely used, there need be no fear of future exhaustion. At present, mankind is relying heavily upon the nonrenewable resources, but there is a definite trend toward substitution of renewable resources for the nonrenewable and a shift toward relatively greater reliance upon annual income than upon stored capital. This bids fair for the future, but the change will be slow. The question is pressing, whether or not the mineral resources are adequate to meet human needs during the next half century.

No nation possesses adequate supplies of all the varied mineral resources to meet its present needs. Domestic shortages of certain substances now available in adequate quantities are very likely to develop in the next few years. The United States is dependent upon Malaya, the East Indies, and Bolivia for tin; upon Canada for nickel and uranium; upon the Soviet Union for ferromanganese. Its petroleum resources have been depleted more rapidly than those of other countries, so that within a decade domestic production of crude oil will not be sufficient to meet the demands.

THE ABILITY OF SCIENCE TO FIND RESOURCES ADEQUATE FOR FUTURE NEEDS

Thanks to science and technology, however, substitutes for some of the nonrenewable resources are already available. Petroleum products, for example, may now be synthesized from coal and oil shale. The known reserves of these carbon-rich rocks in the United States are sufficient to supply the present annual demand for petroleum products for at least 2000 years. The processes, however, are expensive and it would be desirable to import petroleum from abroad, as indeed we began to do in 1948.

Taking the world as a whole, the known and probable reserves of all the essential mineral resources appear adequate to meet the world's needs for several centuries. Although certain of the richest and most accessible metalliferous ore bodies may be exhausted within a few years, there are many lower-grade deposits that may be used when and if it is necessary to rely upon them. Processes of "beneficiation," improved techniques of mechanized mining, and more effective methods of extraction or refining may make it almost or quite as economical to handle such ores in the near future as it is to extract the metals from the richer ores that are now being exploited. At the same time, the potentialities of scientific research should not be under-rated. In our lifetime, men have learned how to extract magnesium from sea water, where it is present in practically limitless quantities; and it is now available as a substitute for aluminum for many purposes. Intensive search for copper, lead, and zinc ore bodies has not yet covered all possibilities in the United States and has scarcely begun in many geologically favorable places in several foreign lands.

There seems to be abundant basis for the expectation that scientific research and technologic development will enable future generations to secure all the required mineral fuels and metalliferous ores for the expanding needs of increasing industrialization and growing populations during at least the next century. Beyond that it is idle to speculate. No man of science can forecast today the achievements resulting from research a hundred years hence.

The optimistic outlook for the near future is, however, based upon a world view. Valuable mineral deposits are unevenly distributed throughout the earth. Certain metals are found in only a few localities. None of the great industrial nations of the world, for example, possesses within its borders adequate supplies of tin. Mineral interdependence will doubtless change from time to time, but it will continue to be a factor with which every nation must reckon. The geology of the earth establishes the directive for free exchange of raw materials, finished products, and technologic knowledge the world around, without hindrance at national boundaries.

FOOD SUPPLY FOR THE GROWING POPULATION OF THE WORLD

The population of the world has approximately doubled in the last hundred years, increasing from about 1.1 billion in the late eighteen forties to about 2.2 billion at the present time. Such a surge of the flood-tide of humanity has never occurred before, and it is altogether unlikely that anything like it will ever recur in the future. Nevertheless the problem of providing adequate sustenance for the rapidly growing family of human beings is a most difficult problem to solve.

Now that scientific research has made possible the fixation of atmospheric nitrogen in compounds suitable to serve as food for plants, the soil resources of the world are at least potentially in the category of renewable resources. We may consider the soil as a factory, rather than as a storehouse. But the factory has a limited capacity. Somewhat less than 20 per cent of the land surface of the globe is suitable for cultivation of crops or grazing of animals.

SOIL EROSION

Much has been said in recent years about the destruction of irreplaceable soil by erosion resulting from agricultural activities. Although it is well to warn people of the very real dangers and stimulate them to adopt better ways of operating the soil factory, it would be a mistake to give the impression that a decrease in the area of arable land is inevitable. Techniques of soil conservation are now available such that the ignorance and sloth of man, not the processes of nature, must henceforth be blamed for any significant reduction in the area of crop lands available for cultivation in future years. Erosion of the land is a geological process that will continue as long as water runs down hill and winds blow. It is inevitably accompanied by deposition of the eroded material. The fertile bottomlands of broad valleys are veneered with rich soil derived from steeper slopes near the headwaters of the rivers. Although the activities of men have often interfered with the processes of nature in such a way as to hasten destruction of valuable farm lands, the mistakes of the past are now well understood by the soil-conservation experts of today. Countless farmers have learned the virtues of contour plowing and the value of cover crops. Land use is being adjusted to local conditions of soil and slope and rainfall. Already much progress has been made in many regions toward preserving the arable lands from further destruction.

Moreover, rich topsoil is not irreplaceable. Gullies may be filled with fertile silt above obstructions that check the run-off, and many abandoned farms may be returned to valuable use in a few years. Now that we know how geologic forces operate in the erosion-deposition cycle, we may take advantage of the vast healing powers of nature and restore much of the damage resulting from the ignorance and short-sightedness of the past.

INCREASING THE WORLD'S FOOD SUPPLY

There yet remain many idle acres of swamp and marsh that may be drained, of arid lands awaiting irrigation, and of tropical "rain forest" that can be put to much more valuable use than at present. The extent to which the area of arable land may be increased by such measures is essentially a matter of economics rather than of geography. It is the expense of building dams, constructing irrigation canals, pumping water or digging drainage channels that sets a limit to the dimensions of the soil factory rather than the size of the continents.

Balancing the many factors, it is however to increased production per acre rather than to increased number of productive acres that we now look for the greatest expansion of the means of subsistence. Improved techniques in agronomy, the use of more efficient fertilizers, new types of seed, better breeds of cattle, and eradication or control of many diseases affecting plants or animals have worked a veritable revolution in the agricultural output of many regions. New varieties of wheat yield better than a hundred bushels per acre, with no more labor, equipment, or fertilizer than were used to produce only fifty or sixty bushels per acre from the best seed available a quarter century ago. The milk production of Europe could be increased at least 5,000,000 tons per year, with no increase in the number of cows or of the food for them, if mastitis were controlled by the use of penicillin in accordance with methods of treatment the success of which has recently been demonstrated.

For many years, the United States has been a vast laboratory for scientific research not only in the more efficient use of the land, but also in the best procedures for inspiring and training farmers to adopt the improved methods. The results are most encouraging. For example, the demonstration program of the Tennessee Valley Authority, begun in 1935 with the cooperation of the U.S. Department of Agriculture, involved nearly 42,000 farms with a total area of more than 6,000,000 acres. By 1942, the production of meat, eggs, and dairy products from all that acreage had increased on the average more than 30 percent, largely as a result of increased use of mineral fertilizers rich in phosphoric pentoxide.

The fact is that we are just beginning to apply the intelligence of science to the most fundamental task of increasing the output of our food factory on a world-wide scale. To take advantage of the great potentialities of the soil requires however the widespread distribution of materials as well as information. Every American, for example, should be proud of the fact that one small item in the program of our assistance to European recovery involved the shipment of hybrid corn to Italy. The planting of that corn in the Po Valley during 1947 and 1948 has increased the per-acre yield there as much as 50 percent.

At the present time, only a small fraction of the world's farmers are putting into practice the knowledge of agricultural procedures now available in the more enlightened regions. If that knowledge could be spread throughout all the farm lands of the earth and if the better strains of plants and animals could be made available everywhere, the soil now under cultivation could provide a high standard of living for at least three billion people.

POPULATION TRENDS IN A PROGRESSIVELY TECHNOLOGIC AGE

Before we can appraise the possibilities for continuing human progress, we must ascertain the probable demands that future populations will place upon the limitations of the means of subsistence as thus determined. It would be erroneous to project the recent extraordinary growth of the world's population into the future and anticipate that the number of people will be doubled in the next hundred years as it was in the last hundred years. Medical research, since the turn of the century, has greatly lengthened the average span of life. A large fraction of the people now living would long since have been dead, were it not for modern sanitation, public health measures, and medical or surgical treatment that was entirely unavailable a century ago. Death rates have declined while the average age of the inhabitants of all technologically progressive communities has been advancing. But this trend is now approaching its limit. In spite of all that modern medical science can do, the death rate will increase in the next few decades among such communities. We are now about "to take up the slack" resulting from the recent lengthening of the average span of life.

Although the ratio between births and deaths in a community is often referred to as the "vital index," that ratio cannot be used realistically as an indication of future rates of population increase. Instead, the demographer depends upon the "net reproduction rate" for his prophecies of future population figures.

In recent years the net reproduction rate of several European countries has been less than unity. England, France, Germany, and Sweden are definitely facing a gradual decline in numbers. In Denmark, Finland, Spain, and Portugal the net reproduction rates closely approximate unity, and those nations now have a fairly stable population. Other countries, including the Soviet Union, Italy, Greece, Poland, and the Balkan states, are reproducing at a rate appreciably greater than that necessary to maintain their present numbers. The net reproduction rate for the United States as a whole is still slightly above unity, although it has fallen just below that figure in certain states along or near the northeastern seaboard and in others bordering the Pacific. The approach toward a stationary population seems to be a perfectly normal accompaniment of the transition from the youthful to the mature stage in the evolution of man, an approach that is now being made more rapidly by the white race than by any other segment of the human family.

Accurate statistics are available for only a small fraction of the yellow, brown, and black peoples of the earth. For hardly any of these can the net reproduction rate be determined with precision. Even less available are the data necessary for ascertaining the changes, if any, in the reproductive index during the last fifty years. Fairly definite trends are however discernible, even though the data are incomplete.

Since 1900, the colored races have made considerable progress toward attaining the white man's death rate. In that advance the medical missionaries and the philanthropic foundations' doctors from the United States have lent an efficient helping hand. Progress toward attaining the white man's birth rate has been appreciable but much less rapid. Consequently, for the next few decades the colored peoples will increase in number more rapidly than the white. But the many complex and often subtle factors in human nature that bear upon reproductivity seem to be essentially the same, regardless of the pigmentation of the skin. The crude birth rate in India declined from an average of 33.3 per 1,000 per year in 1926–30 to 27.9 per 1,000 in 1946 and that in Japan from an average of 33.5 per 1,000 in 1926–30 to 26.5 per 1,000 in 1946. In time—three or four decades for some communities, six or eight for others—the balance between fertility and mortality among colored peoples will be similar to that among white people.

With the application of the intelligence of modern science to the problems of everyday life, there has invariably been a sharp increase in the rate of population growth, followed by a levelling off toward a stable condition. Certain regions have already attained what seems to be an all-time maximum of inhabitants. Others, the United States being one of them, are rapidly approaching that condition of stability in numbers. And these are the regions that enjoy the highest standard of living of all communities.

Projecting the curves of population growth from the first half of the twentieth century and applying the pattern of the white man to the future of the colored man, it would appear that the world population will become practically stable by the middle of the twenty-first century. The future maximum population of the entire world would then be in the neighborhood of three billion, certainly not more than three and a half billion.

POTENTIAL ABUNDANCE IN AN INTERDEPENDENT WORLD

There seems to be no reason for fear that with a continuation of the present trends in the agricultural sciences the soil resources will prove inadequate to provide a good standard of living for that prospective maximum population of the earth. Forty percent of the inhabitants of the earth are now living under conditions to which the Malthusian principle does not seem to apply. The rate of population increase is not for them determined by any limitation upon the means of subsistence. The other 60 percent are apparently under the Malthusian restrictions. They include the closely crowded masses of India, China, and southeastern Asia. But because of ignorance and exploitation these people are not taking full advantage of the opportunities that modern science and technology can provide for increasing vastly the means of subsistence. May it not be true that if they are given the assistance and the freedom that they need, they too will achieve a relationship between themselves and their environment similar to that of the more fortunate 40 percent?

The renewable resources of the soil cannot be used to best advantage without drawing heavily upon the nonrenewable resources of mineral fuels and metalliferous ores—at least not in the foreseeable future of the next fifty years. Mineral interdependence will shift in degree and kind, with the progress of research, but it will certainly be with us for many years to come. In an age of science and technology, no man, no community, no nation can live to itself alone. Potential abundance can be made a reality only if we accept the accompanying fact that ours is an interdependent world. The "road to survival" cannot be traversed by a small fraction of the human family if the rest are left behind.

The task we face at this midpoint of the Twentieth Century is difficult beyond words. To take advantage of the rich resources of our bountiful earth in such a way as to enable each inhabitant of the world neighborhood to have a fair chance for a decent standard of living will require the mobilization of all the intelligence that mankind possesses. But even that will not be enough, unless there is also a great increase in the dynamic of good will. Sympathetic consideration for the rights and needs of others seems now to be an absolutely inescapable prerequisite for the successful adjustment of humanity to its environment. Mother Earth is rich enough to nourish every man in freedom, but it is by no means certain that every man is prepared to accept the responsibilities of living in freedom.

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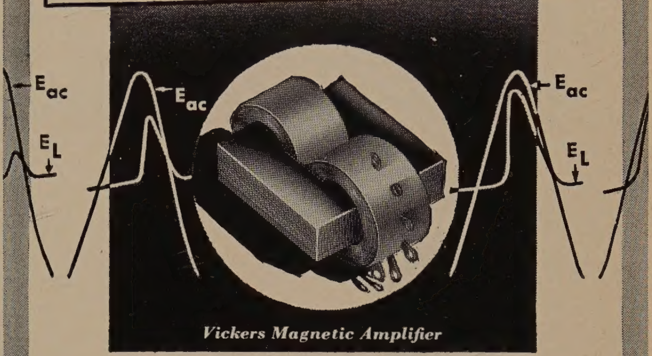

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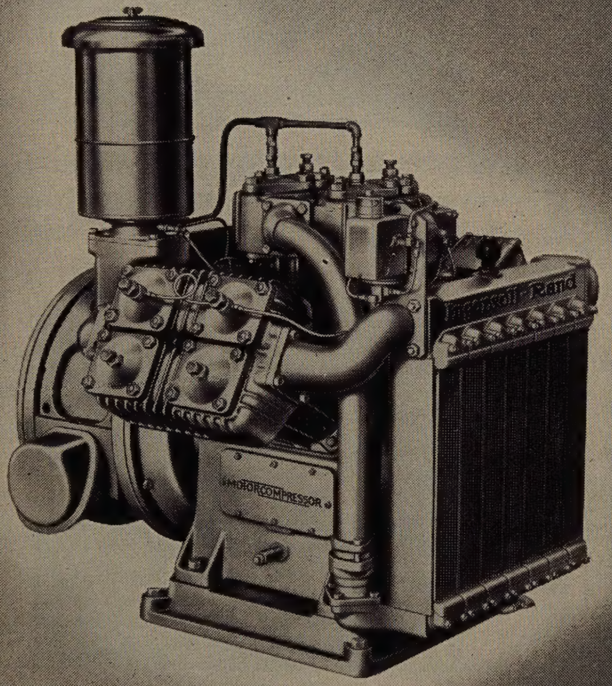

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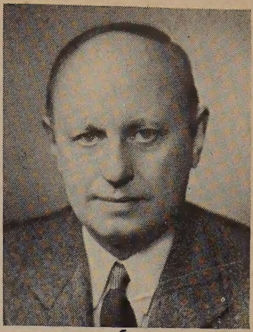
REVOLUTIONARY ADVANCE IN INSTRUMENT TRANSFORMER DESIGN

Result of co-operative research and development to produce a superior instrument transformer by using molded butyl as insulation instead of wrapped and impregnated paper



I F Kinnard

By I. F. KINNARD
Manager of Engineering, Meter and Instrument Divisions
West Lynn Works, General Electric Company

DURING more than fifty years of continuous manufacture, it has been almost universal practice to insulate dry-type instrument transformers by wrapping a fibrous material—commonly varnished cambric or crepe paper—around the transformer coils and then impregnating this matrix with asphalt or a similar insulating compound. In many designs, as much as one-quarter mile of crepe paper has been wrapped on the coils for proper insulation. Because of the complex configuration of the coils, most of this wrapping has been done by hand. It has, therefore, long been the goal of instrument-transformer engineers to develop a method of molding or casting an insulating material around the transformer core and coils, thus eliminating the necessity for hand wrapping. After considerable experimentation such a method, as well as a material suitable for use with the method, has been developed through the joint efforts of several divisions within the General Electric Company. The result is the butyl-molded current transformer illustrated in FIG. 1.

This transformer is of unit construction, with all the component parts firmly molded together in a continuous casing of butyl, as shown in the phantom view FIG. 2. Its performance characteristics represent a distinct improvement over older designs of transformers and are due in large measure to the excellent properties of butyl and to the new concept of molded transformer insulation.

BACKGROUND OF DEVELOPMENT

The search for a practical method of casting insulation around the core and coils of a transformer began as long ago as 1930, when a mixture of Portland cement and sand was tried by General Electric engineers. Because it tended to crack after hot-and-cold temperature cycling, however, this material was not successful. During succeeding years, twenty-eight additional materials were tried with various molding and casting techniques. These included Catalin, tried in 1936 and again in 1944; asphalt-impregnated Portland cement tried in 1938; solventless varnish in 1943; phenolic resins with various fillers in 1944; silicone rubber in 1945; and a host of others. Many individual difficulties were encountered with these materials, but, in general, they tended to crack during temperature cycling which expanded and contracted the metal parts of the transformer. In addition, they were difficult to mold or cast without voids.

Late in 1945, a synthetic gum was tried with very promising results. This material is one of the group of synthetic elastomers known as butyl. This is a product made from petroleum by reacting two of its derivatives, isobutylene and isoprene, at very low temperatures to

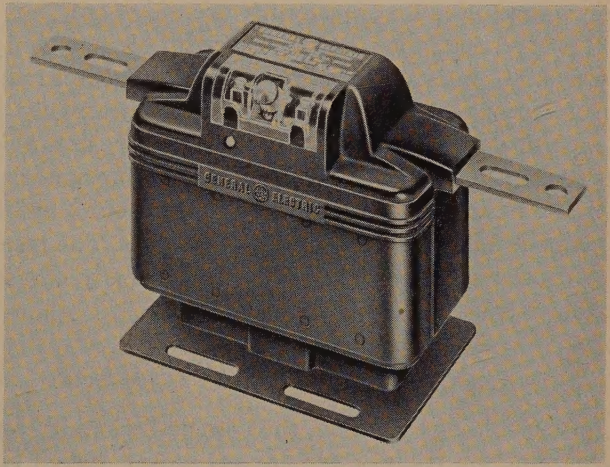


Fig. 1. Exterior view of the new butyl-molded current transformer

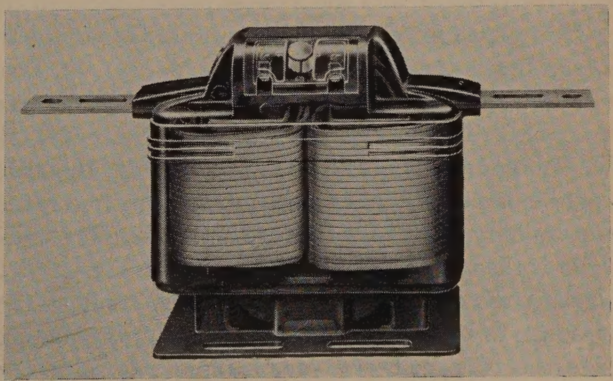


Fig. 2. Phantom view of the current transformer of new design

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form giant molecules having a molecular weight of up to 80,000. For comparison, the molecular weight of aluminum is 27. Butyl is flexible enough to withstand extreme dimensional change in the metal parts, and the pressure used in molding gives a dense, homogeneous insulation with no voids. The search for the ideal material was thus narrowed to one basic type.

To obtain the maximum advantage from that material, however, it was necessary to develop a special butyl compound that would best suit the needs of molded transformer insulation. The developing of that compound was delegated to the Company's Bridgeport Works Laboratory, which several years previously had actively participated in the development of a butyl gum expressly designed for electric insulation of power cables. This basic material is characterized by a high degree of saturation, which left very few unstable molecules that would tend to combine with oxygen and thus cause a general degradation of the properties of the material. This is particularly important for electric insulation since high temperature and the formation of ozone during corona discharge tend to accelerate the normal oxidation effect and shorten the life of the insulation. These properties, originally developed in the material for use as cable insulation, are equally well suited for transformer insulation, so this basic gum was selected for transformer use.

However, less than half the weight of most butyl compounds consists of butyl gum; the remainder is made up of various filler materials which impart many of the physical and chemical properties that are desirable. Consequently, various combinations of filler materials with the basic gum were prepared and tested to obtain a compound having the required properties. The result is a special compound developed specifically for instrument-transformer molded insulation.

TECHNIQUE OF MOLDING

In the molding operation, the core and winding components of the transformer are assembled, baked out completely, and properly positioned in a hot cast-iron mold. Butyl is then injected into the mold under controlled pressure and temperature. When the mold is completely filled, a mechanical shut-off is closed to retain the pressure and the mold is placed between two hot steel plates for curing. After curing, the completed transformer is removed from the mold (FIG. 3). Since the nameplate information and the polarity markings are molded directly into the surface of the butyl, the only subsequent operations are to remove the flash, color the nameplate and polarity markings, and attach the secondary terminal hardware and cover. The transformer is then ready for final inspection and test.

During the development stages, many samples were cut apart to determine the condition of the material inside the transformer. Every sample was x-rayed so that the position of the parts could be studied. Complete tests were made to determine the exact quality of the completed samples. While many problems were encountered in developing the molding process, a satisfactory molding technique has been established.

PROPERTIES OF BUTYL

Exhaustive tests on the butyl itself, and on complete molded transformers, were made by our Bridgeport Works Laboratory, the Meter and Instrument Laboratory, and the General Engineering and Consulting Laboratory. From these tests and other critical examinations, the properties of the special butyl compound were found to be ideally suited for the purpose.

Physical Properties

The cutting resistance, tear resistance, thermal conductivity, and resistance to abrasion of the butyl selected are all higher than necessary for the application. The tensile strength is greater than that of older insulations and is more than adequate to hold the parts of the transformer firmly together under all conditions of mechanical shock due to electrical overloads or even accidental rough handling. Since it has an elongation of 680 per cent, when tested in accordance with American Society of Testing Materials procedure, these mechanical shocks will not crack the insulation, but will flex it slightly. The butyl absorbs the energy of the shock and then returns to its original shape unharmed. The ability of the first butyl-molded transformer to withstand momentary overloads of 180 times full-load current without mechanical damage stems from the excellent physical properties of the butyl insulation.

Chemical Properties

An ideal insulation compound must operate satisfactorily under the adverse atmospheric conditions occasionally found in places where current transformers are located. The remarkably stable chemical properties of the new butyl compound make it ideal for almost all conceivable conditions.

Although the first butyl-molded transformer is designed specifically for indoor use, it is expected that future designs may well be suitable for both outdoor and indoor applications. Evaluation of the material for such application is proceeding. Tests made in a weatherometer, which subjects the sample to alternate water spray and ultraviolet radiation, indicate no deterioration after 1000 hr of test. Thirty months' exposure to high humidity also shows no visible signs of degradation of the material tested.

The resistance of butyl to alkalis and acids is very good; thus, atmospheres that contain acids or alkali in suspension will not affect transformers insulated with this material. In common with most other insulating materials, however, butyl is affected to some degree by organic solvents.

Electrical Properties

In the selection of an insulating material, electrical properties are of primary importance. Extensive tests for dielectric strength, power factor, resistance to flashover, and other electric properties indicate that butyl compares very favorably with older-type insulating materials.

The dielectric strength of butyl under 60-cycle insulation-breakdown tests averages approximately 400 volts per thousandth of an inch for samples 1/8 inch in thickness. This is almost double the comparable value for asphalt-impregnated paper. In contrast to that of other materials, moreover, this dielectric strength remains high even when the temperature of the insulation is raised to a level far above the normal operating range. Asphalt-impregnated paper, for example, suffers a forty per cent reduction in insulation-breakdown strength when the temperature is raised from 25 to 100 C, which is within the operating range. Less than half this reduction is experienced with butyl, even when the temperature is raised from 25 to 130 C, which extends above the operating range. This means that, with butyl, the safety factor, represented by the amount the insulation voltage exceeds the operating voltage, remains at a high value despite considerable rise in temperature.

Fig. 3. Final operation in butyl-molding the new transformer

Another significant factor in determining the suitability of an insulating material is its power factor. If the power factor is too high, leakage losses through the insulation will cause internal heat to be generated, which action will shorten the life of the insulation. In the case of butyl, the power factor of less than 1.0 per cent falls well below that of most other solid dielectrics.

The ability of butyl to withstand repeated flashovers without formation of a low-resistance surface path is excellent. Arc-tracking tests, made in accordance with American Society of Testing Materials procedure, show that butyl will withstand 130 sec of repeated arcing, compared with 7 sec for ordinary phenolic materials; 90 sec for polyethylene; and 130 sec for asphalt-impregnated paper.

Life Tests

In addition to having so many excellent properties, however, a material is suitable for use as transformer insulation only if its life equals or exceeds the thirty-to-forty years' operation span normally expected with instrument transformers. Accelerated life tests made on butyl transformers under extremely adverse conditions indicate a life expectancy well over these requirements.

Inasmuch as high temperature will in general deteriorate organic insulation very rapidly, several butyl-insulated transformers were operated at temperatures far in excess of normal to determine within a relatively short time the life expectancy of the new design. ASA Standards for service conditions require instrument transformers to operate in ambient temperatures up to 40 C with an average temperature over a 24-hour period not to exceed 30 C. By modified loading, the upper limit can be extended to 55 C.

The accelerated life tests made on butyl-insulated transformers were run at the substantially higher ambient temperatures of 121 C and 150 C, and with 15 per cent above rated voltage applied continuously. For purposes of control, several transformers insulated with asphalt-impregnated paper were included in the 121 C test, but only butyl transformers were subjected to the 150 C run because that higher temperature would have melted asphalt-type insulation. During the tests the transformers carried full-load current for twelve hours out of every twenty-four which, under the test conditions, resulted in a 30 C temperature rise in the windings. Thus, for half of the test period the transformer windings operated at 180 C for the 150 C test, and at 151 C for the 121 C test.

Mechanical-shock tests, as well as high-potential and other electrical tests, were made on the transformers at intervals during the life-test period. Under these extremely adverse conditions of application, the four transformers in the 150 C test have operated for 1500 hr without incident, and 2200 hr have been recorded for transformers on the 121 C test. Although the asphalt control samples in this latter test have survived electrically, serious mechanical defects have been noted, characterized by cracks and charring of the insulation and by melting of the asphalt. The mechanical condition of the butyl transformers showed little change during the test.

These test results cannot be interpreted directly in terms of operating life under normal conditions because the development of butyl insulation has been too recent to permit a direct correlation between accelerated tests and actual life. However, the results of the tests indicate that butyl-insulated transformers should have a longer service life than superseded types that are insulated with impregnated fibrous material.

The effect of repeated change in temperature and humidity conditions was checked by cycling a group of four transformers between −40 C, +75 C, and 90 per cent relative humidity at 40 C. The transformers

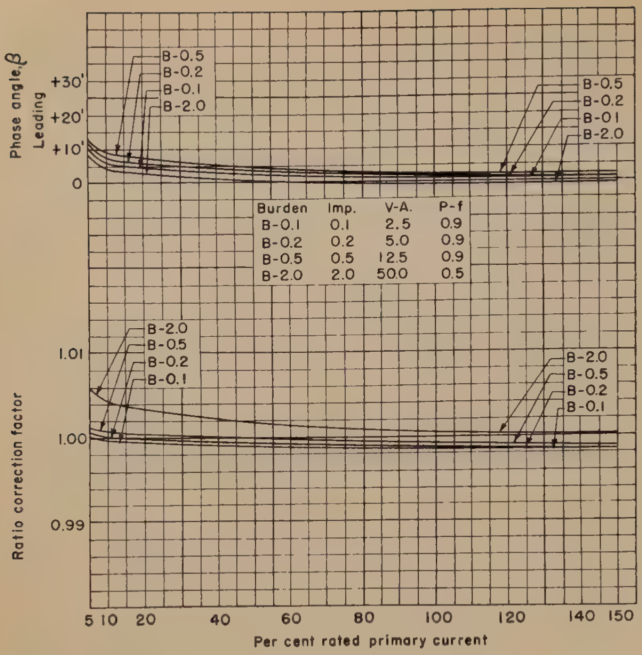

Fig. 4. For normal current range and 60 cycles: the ratio and the phase-angle characteristics of the new current transformers of 5000-volt, 10- to 800-amp rating

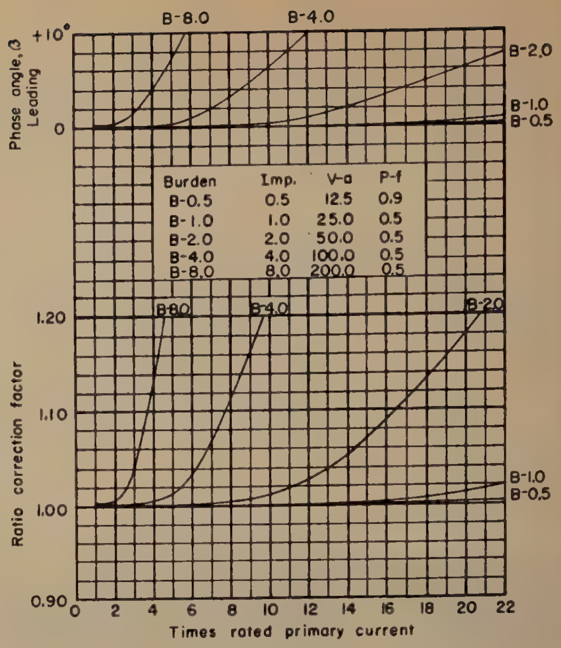

Fig. 5. For over-current range and 60 cycles: the ratio and the phase-angle characteristics of the new current transformers of 5000-volt, 10- to 800-amp rating

were left, without voltage or current, in each condition for 24 hr and were moved directly from one condition to the next. Eleven hundred hours of test have been recorded without incident. Here again, both butyl-insulated and asphalt-paper-insulated transformers were included in the tests, and although electrical failure did not occur in either type, there were marked indications of surface cracking on the asphalt-paper transformers. Tests at intervals showed no change in the transformer properties.

FIRST BUTYL-MOLDED-INSULATION TRANSFORMER

The first design to incorporate the new technique of molding butyl insulation around transformer parts is for current transformers having all ASA current ratings from 10 through 800 amp and suitable for 5000-volt service. These transformers have the highest ASA accuracy classification for all metering burdens; and, excepting only the 800-amp transformer, all are capable of continuous operation at 150 per cent of rated current. Additional performance data are given in Figs. 4 and 5.

The use of butyl insulation in this design results in many improved characteristics. Primarily, better insulation is achieved—insulation that will withstand a wide variety of operating conditions. Sunlight, high humidity, high temperature, arc flashover, acid- or alkali-laden atmosphere—all of these affect butyl very slightly; most of them affect older insulations to a much greater degree. A strong transformer is made possible because the one-piece butyl construction holds the parts firmly in position; yet the butyl is resilient enough to absorb, without cracking, the shock of high momentary overloads and rough handling. More consistent quality is made possible, both in dimensions and insulation characteristics, since the relation of parts is determined by the mold and, thus, is not subject to the human vagaries of hand insulating. Improved appearance is achieved with butyl-molded insulation as can be seen from the comparison of new and old shown in Fig. 6.

In addition to these immediate advantages, the development of butyl-molded insulation also has many broader implications. The process is, for one thing,

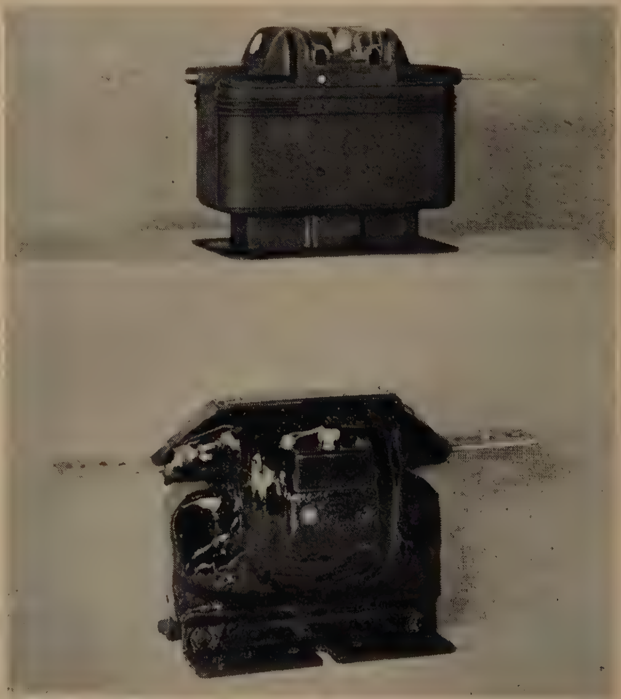

Fig. 6. Comparison of the new (*above*) and the old (*below*) instrument current transformers, graphically showing the attractive and neat appearance of the new design

more adaptable to mass-production methods than older techniques. Then, too, the possibility of using this insulation eventually for outdoor transformers—transformers that might well be as light and convenient to use as present indoor designs—is of great significance. In fact, this new butyl-molded transformer represents the first step in an entirely new approach to instrument-transformer design.

A revolutionary method of insulation, however, is not the only factor in the superior performance characteristics of the new transformer. The core is made of a silicon-steel strip that is characterized by having high permeability and low losses in the direction of rolling, but poorer qualities when the flux is made to flow across the grain. As may be seen from Fig. 7, full advantage has been taken of these directional properties by designing the core so that the flux always flows along the length of the strip.

Of course, the best possible properties would be obtained if the core were wound from a continuous strip without joints. Inasmuch as this is impractical from the standpoint of assembling the windings onto the core, the best compromise is attained with the interleaved joints also shown in Fig. 7. This type of joint provides the maximum stability for accuracy, since there is no possibility that a shift in core position will change the reluctance of the joint.

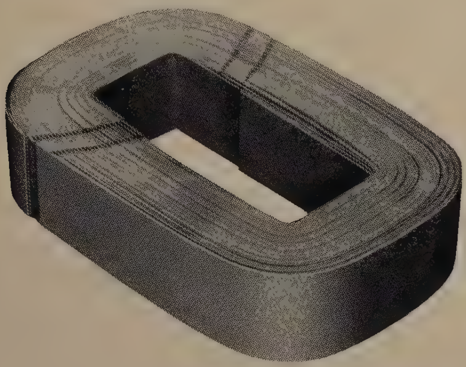
Fig. 7. The formed core with interleaved joints

The windings are also especially designed to give outstanding performance characteristics to the transformer. As shown in Fig. 8, the "figure-eight" primary winding encloses two secondary coils, which are in turn mounted on the legs of the core. This construction distributes the total winding around the core as much as is practical, and places the joints of the core inside the windings where the leakage flux is low. Both of these factors contribute toward the high accuracy of the design.

The two-section windings also make possible a continuous rating of 150 per cent of rated current up to 800 amp and the mechanical ability of the transformer to withstand momentary overloads of 180 times rated current. The heat developed by continuous overloads is distributed over a wide area by the two-section coils, resulting in rapid dissipation. As a result, the continuous overload capacity of this transformer is achieved without increasing the cross section of copper over that used on older designs. The large forces developed in the windings by momentary overloads of a high value are also divided between the two parts of the coils. Thus, very much greater overloads can be handled than is possible with other types of construction.

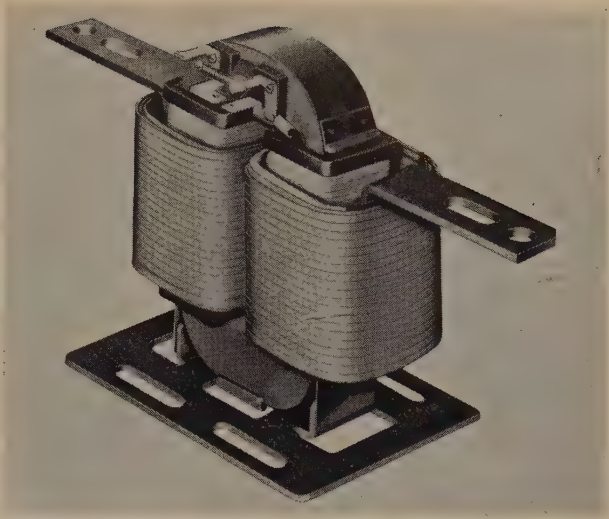
Fig. 8. The core and coils before the butyl-molding operation

SUMMARY

The new current transformer described in this article has revolutionized the design and manufacture of dry-type instrument transformers. Laborious hand-wrapping methods of insulation have been replaced by a molding process that gives homogeneous insulation of unit construction with appearance and performance characteristics far superior to older designs. A new concept of insulation design has been introduced, not only for instrument transformers, but for other electromagnetic devices as well.

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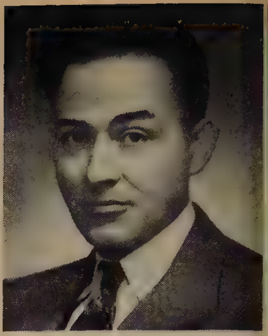

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A highly versatile and valuable tool for the study of rapid motion. Compact, portable, operable in any position, it makes possible the recording of phenomena occurring at speeds beyond the scope of ordinary photographic technique

By W. R. PLANT
General Engineering and Consulting Laboratory
General Electric Company

CONTRARY to popular conception, high-speed photography, utilizing electrical discharge phenomena, is not a new art. In 1851 Henry Fox Talbot patented in England the use of an electric spark for instantaneous photography. Professor E. Mach made photographs of speeding bullets at the University of Prague in 1881, and Sir Charles Vernon Boys(1) made shadowgrams in England in 1893. Shadowgrams taken at the National Bureau of Standards by P. D. Quayle(2) are excellent even by today's standards. Because mechanical shutters are limited to 10^{-3} seconds duration or more(3), modern workers sought better means, and returned to the ideas of spark photography first advanced by Talbot and Mach.

Professor H. E. Edgerton and his associates(4) made extensive tests with gas-filled flashtubes and demonstrated their utility for this type of photography. What is believed to be the first commercially available light source having the incredibly short flash duration of 4×10^{-6} seconds was introduced by the General Electric Company several years ago(5). Continuation of work in the field of high-speed photography has produced a newly designed and improved photolight embodying several unique features and capable of producing flash exposures of 2×10^{-6} seconds.

This new unit, with certain problems and details of its design, is here presented. In addition, available accessory equipment is described, and a few brief comments made on choice of negative materials and development technique. A few high-speed photographs made with the photolight and conventional camera equipment are included.

MICROSECOND EXPOSURES

The new photolight makes possible the photography of phenomena occurring at speeds beyond the scope of ordinary photographic techniques. It provides a flash of highly actinic light having a photographically

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

(1)Numbered references are listed at the end of the article.

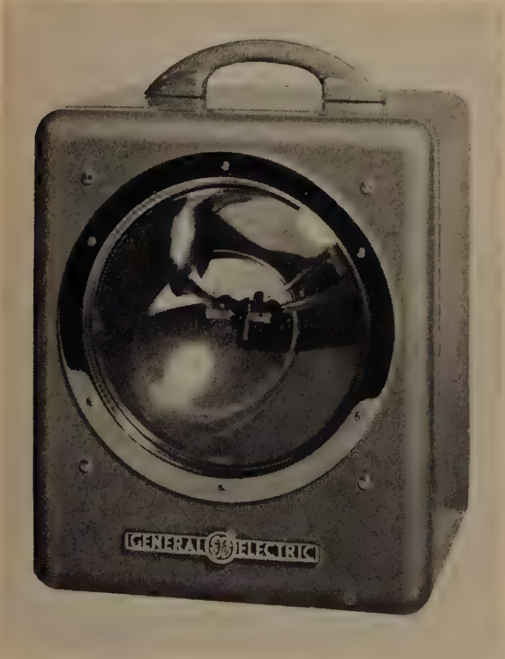

Fig. 1. This view of the photolight shows the flashtube in place. The unit contains also capacitor and control

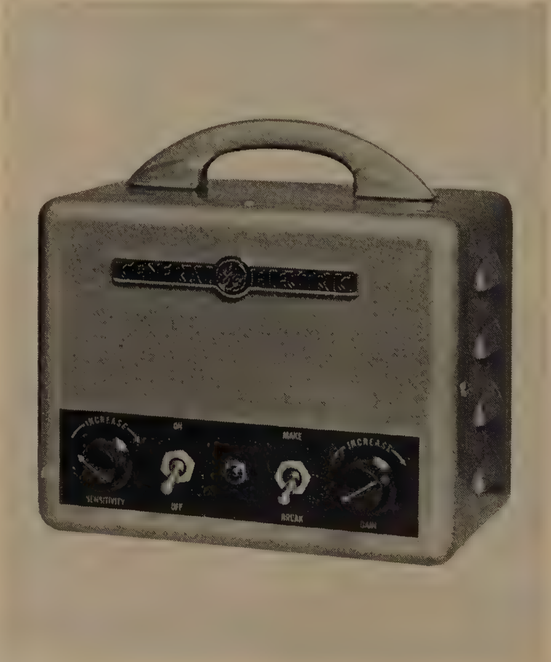

Fig. 2. Photolight amplifier, with operating controls on the front of the case initiates flash from unusual or weak signals

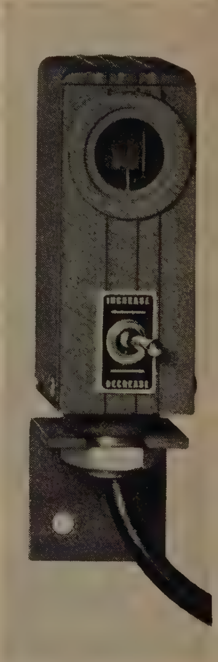

Fig. 3. Phototube preamplifier also supplies the signal initiating the flash

effective duration of 2×10^{-6} seconds or less, and is capable of repeated operation at five-second intervals.

The unit is compact, easily portable, and can be operated in any position. Only conventional camera equipment and sensitive materials need be used, and the design incorporates a number of different methods of synchronizing the flash with the phenomena to be photographed. By use of such accessories as the photolight amplifier, phototube preamplifier, and crystal microphone, it is possible to photograph practically any transient phenomenon.

The photolight is illustrated in FIG. 1. Basically, the unit combines a flashtube, which produces the light flash, an energy-storage capacitor, means for charging the capacitor preparatory to making the exposure, and control for initiating the flash at the precise moment required. The unit is enclosed in a drawn steel case, with carrying handle, weighs 25 lb, and operates from 115-volt 50/60-cycle power, with approximately 50 watts required. The photolight flash may be initiated by operation of a push button on the back of the case, by closing of normally open contacts wired to a jack on the control panel, or by means of a signal received from the amplifier.

The photolight amplifier, shown in FIG. 2, contains circuits which permit the flash to be initiated by relatively weak electric signals from a crystal microphone or from the phototube preamplifier, FIG. 3. All connections to the photolight, including power connections, are made through a single cable three feet long. Jacks are provided for connection of the phototube preamplifier, microphone, or operator's synchronizing circuits. Two controls are provided for adjustment of amplifier gain and sensitivity.

Although a detailed treatment of the electronic circuits employed in these equipments is not within the scope of this article, certain features of the circuits and components warrant brief mention.

SAFETY MEASURES

It is well known to those familiar with flashtube circuits that the very high voltage employed, and especially energy-storage capacitors, can be dangerous. In the design of the photolight here described, the safety of the operator and his equipment have been given the utmost consideration. Interlocks prevent operation of the unit when removed from the case for inspection or repair. The high-voltage transformer is built with a grounded shield between windings. The flash capacitor is provided with a bleeder resistor, and all control power is derived from a separate, isolated source. Wherever possible, circuits are fail safe, protecting the operator and the equipment from injury in case of failure.

The Type FT-130 flashtube used with this light-producing equipment was developed specifically for that service and is unique in several respects. A short-gap high-pressure three-electrode argon arc and a self-contained parabolic reflector have been combined in one hermetically sealed, easily installed unit. All electrodes are brought through fernico seals at the rear, and the front window is sealed to the reflector during manufacture. All glassware is molded Pyrex. The flashtube is approximately seven inches in diameter; the arc, at the focus of the parabola, is approximately eight millimeters in diameter. The bulb is mounted in such a way that no mechanical strains are imposed on the fernico seals.

Life expectancy of the flashtube is exceptionally long, and replacement expense is practically nil. A typical flashtube delivered, at the rate of one flash every five seconds, more than 70,000 flashes before blackening of the bulb became apparent. This blackening, due to condensation of sputtered electrode material, by no means marks the end point of useful life, if allowance is made for reduced light output. Based on a life of 100,000 flashes, at the rate of one picture every ten minutes each working day, the expected life is eight years!

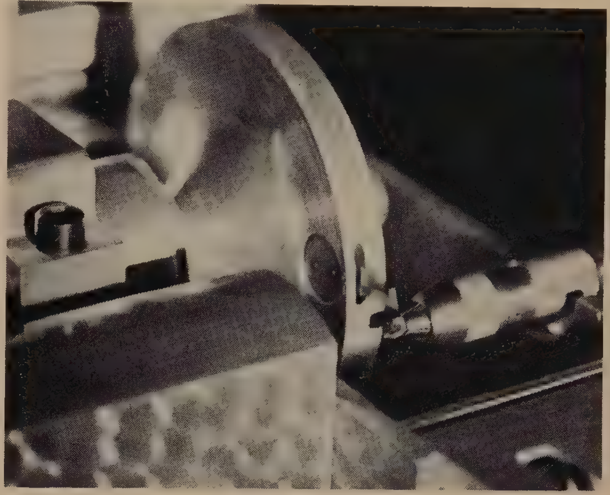

Fig. 4. Unretouched close-up view of a microtome blade traveling at approximately 900 ft per sec (48,000 rpm)

The energy-storage capacitor employed in the photolight was also specially developed. Rated 2 mfd, 3 kv, it is of noninductive design with exposed-foil construction. This design was chosen for its inherent low inductance, high current-carrying capacity, and over-all sturdy construction.

OPERATING TECHNIQUE

Operation of the photolight is relatively simple. Only 115-volt 50/60-cycle power is required, and warm-up time is only 45 seconds. The unit can be operated in any position. All controls are located on the back of the unit, and in general, both photolight and camera can be manipulated by a single operator. A typical setup of the photolight, amplifier, and camera for the study of high-speed microtome sectioning of specimens prior to electron microscopy is shown in the Frontispiece. (FIG. 4 is an unretouched photograph of the microtome blade rotating at 48,000 rpm.) The small size of the equipment is appreciated when working in close quarters.

It is important to remember that photolight photography is essentially "open-flash" and that the camera shutter serves only to exclude general illumination from the film or plate before and after the actual exposure is made. This statement holds true even when the photolight is triggered by means of a camera shutter having built-in contacts.

In this connection, it should be noted that only shutters of the "X" type* are satisfactory. Those shutters having a built-in anticipation time of 5 to 20 ms for use with conventional flash bulbs will initiate the photolight flash before the shutter is open, and only blank film will result. Use of the "X" type shutter permits manual synchronization under ordinary or subdued room illumination without introducing any noticeable adverse effect.

TRIGGERING

Where the event to be photographed cannot be anticipated accurately, or is beyond the control of the operator, it is necessary to sequence operations so that the camera shutter is open when the flash occurs. In general, this condition requires a working area of low illumination level, keeping the room-light contribution to the film density at the minimum, and some automatic means of coupling the phenomenon which is to be photographed to the initiation of the photolight flash.

Where the phenomenon is under control of the operator, it is sometimes possible to employ the one-second shutter setting found on some modern camera shutters, by causing the event to occur during the one-second period that the shutter is open. Of course, the shutter contacts cannot be used with this technique, and it is necessary to cause the object being photographed to trip the photolight at the moment required.

This phase of photolight photography provides the operator with an excellent field for experiment and will occasionally tax his ingenuity to the utmost. It was with such problems in mind that versatility of triggering means was incorporated in the photolight design. In recording continuous or cyclic motions or those transient events which can be manually synchronized with sufficient precision to give good results, the unit can be triggered by operation of the push button on the control panel. Oscillatory or rotary motion within the camera field or continuous events such as water streams, fuel sprays, and the like might fall within this category.

Where it is possible to cause the phenomenon being photographed to operate normally open contacts, the contacts may be wired to the jack on the control panel; they will thus automatically carry out the initiation of the flash. Auxiliary contacts such as colliding wires or foils, contact-making microphones, and other normally open devices suggest themselves. These contacts operate at approximately 80 volts and need carry only a few milliamperes. Because of time-constant limitations of the circuit, it is necessary that the normally open contacts remain closed for approximately one millisecond, although no damage results if they remain closed indefinitely.

AMPLIFICATION

When the condition of normally open operation—one millisecond closed time—cannot be met, it is necessary to employ the amplifier shown in FIG. 2. This unit is capable of initiating the flash by opening normally closed contacts, or by closing normally open contacts which remain closed for only a few microseconds.

A jack is provided for connection of a crystal microphone or other high-impedance sources of pulse signal such as certain types of strain gages and accelerometers. When working with a microphone it is possible to introduce a time delay by placing the microphone at some distance from the scene, remembering that the velocity of sound in air is approximately 1100 ft per sec. Thus a 1.1-ms time delay is introduced for each foot of space between the source of sound and the microphone. When a signal is supplied by the phototube preamplifier, shown in FIG. 3, it is possible to initiate the flash by either breaking or completing a light beam.

If required, the "trigger" beam may be of infrared wavelength, which does not affect the usual photographic materials. This is important in photographing flying or falling objects from which light from the trigger beam may be reflected, introducing spurious streaks or halation into the photographic record. If smoke is present, light scattered from the smoke particles may be recorded, with attendant loss of contrast in the photograph.

LUMINOSITY

A word of caution must be inserted regarding flash photography of self-luminous and, particularly, fluorescing materials. Because of their very nature, self-luminous materials do not lend themselves to photography by the open-flash technique; emitted light from the object will be photographed as a streak, the length of which is a function of the particle velocity and the total time the shutter is open.

A fluorescent or phosphorescent material (the terms differ only in the rate of decay of luminosity) exhibits the same effect as the self-luminous, provided its excitation wavelength falls within the radiant-energy spectrum of the photolight. Since the FT-130 flashtube is constructed of Pyrex glassware, passing light of fairly short wavelengths, it is possible to excite some materials to fluoresce within the sensitive range of photographic materials. This may result in their remaining luminous for an appreciable time after the initial excitation by the flash is removed. This phenomenon can be a beneficial or a detrimental factor, depending on the type of study being made.

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*A type of shutter used in synchronizing high-speed electronic flash units.

The effect is useful in tracing the direction taken by individual particles, since they are recorded as streaks. However, if it is desired to study the size and shape of the particles, the streaks can be eliminated by filtering out the offending excitation radiation at the light source. This can usually be accomplished by mounting a sheet of plain window glass over the flashtube. In extreme cases it may be necessary to employ such ultraviolet-absorbing filters as the Corning Noviol No. 3389 and Wratten No. 2. It is well to remember that practically all the hydrocarbons, as well as a large number of organic dyes and some minerals, paper, and plastics, fluoresce to some extent.

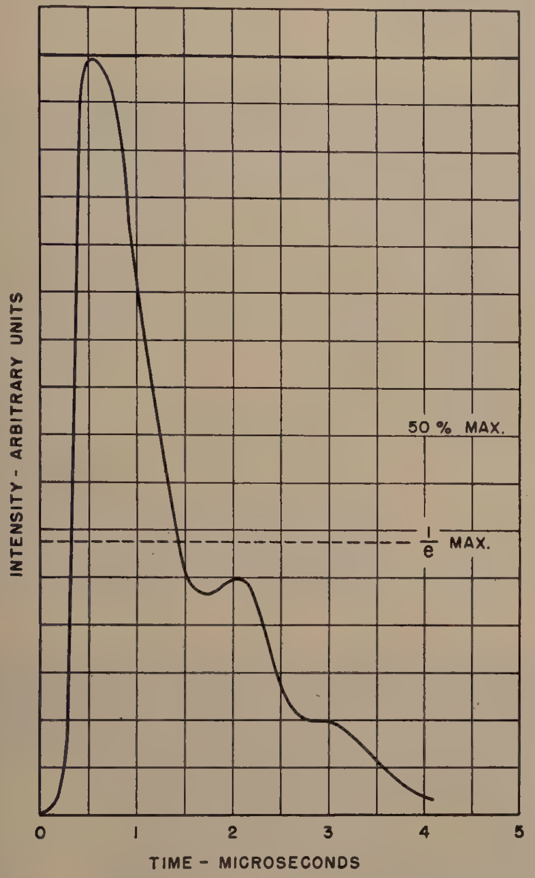

Fig. 5. Typical time-intensity curve of the photolight flash, indicating the instantaneous emf across a resistor connected in series with a high-vacuum blue-sensitive phototube

CAMERA EQUIPMENT

Although the simplest box camera is capable of making satisfactory pictures with the equipment described, convenience and versatility dictate more complex camera equipment. A ground-glass focusing-type camera is practically essential. Interchangeable use of film packs and cut sheet film is indicated. Such features as rising and falling front and swinging and revolving back add to the camera versatility, permitting photography of problems where depth of field is important.

The lens should be a high-quality anastigmat, preferably with low-reflectance coating of all elements. The lens aperture should be of at least f:6.3, and preferably of f:4.5. In general, the shutter speed is of little consequence, since its only purpose is to exclude light from the film before and after the actual exposure. Negative size is optional but should correspond with one of the three sizes most widely used in press work. This choice is dictated by the commercial availability of film material.

Since photolight photography depends on such high peak illumination, cumulative saturation effects, reciprocity failure, and other phenomena not often encountered in conventional photography become a serious problem; their combined effect is to reduce film speed and contrast. Offsetting this, the use of "contrasty" films and developers is indicated. In general, the faster panchromatic press-type films and process developers yield the best results. The so-called fine-grain materials usually produce a negative of insufficient contrast, and the process materials are too slow for good results.

Fig. 5 shows a typical time-intensity curve of the photolight flash. The data were obtained by use of a cathode-ray oscilloscope with a single driven sweep of five microseconds' duration. The curve indicates the instantaneous emf across a resistor connected in series with a high-vacuum blue-sensitive phototube.

Elaborate precautions were taken to insure adequate frequency response and photometric linearity in the measuring circuits. No attempt was made to assign absolute units to the vertical scale, since such data serve little useful purpose in view of film saturation and reciprocity-failure effects. It is sufficient to state that average subjects may be photographed with lens apertures of f:8 or f:11 and the faster panchromatic-sensitive materials. Although lacking in contrast when judged by existing standards, satisfactory negatives have been made at f:22.

In common with all capacitor-flashtube light sources, the actual duration of the flash is long, compared to its photographic effectiveness, because of the relatively weak illumination produced by the tail of the time-intensity curve. Accordingly, in evaluating such a curve it is necessary to resort to the usually accepted convention and consider the flash duration as that part of the curve above one third of the peak value. On this basis, the photolight flash duration is approximately 1.2 ms for a typical unit. This rather arbitrary convention assumes optimum exposure and development manipulations, as objectionable blurring contributed by the tail can result from overexposure and prolonged development.

The spectral quality of the photolight flash is ideally suited to black-and-white photography, but considered too low in red content for satisfactory color work. The quartz spectrograph reveals significant amounts of energy in the near-ultraviolet region. This short-wave energy makes for high actinic quality and is responsible for the fluorescent effects previously described.

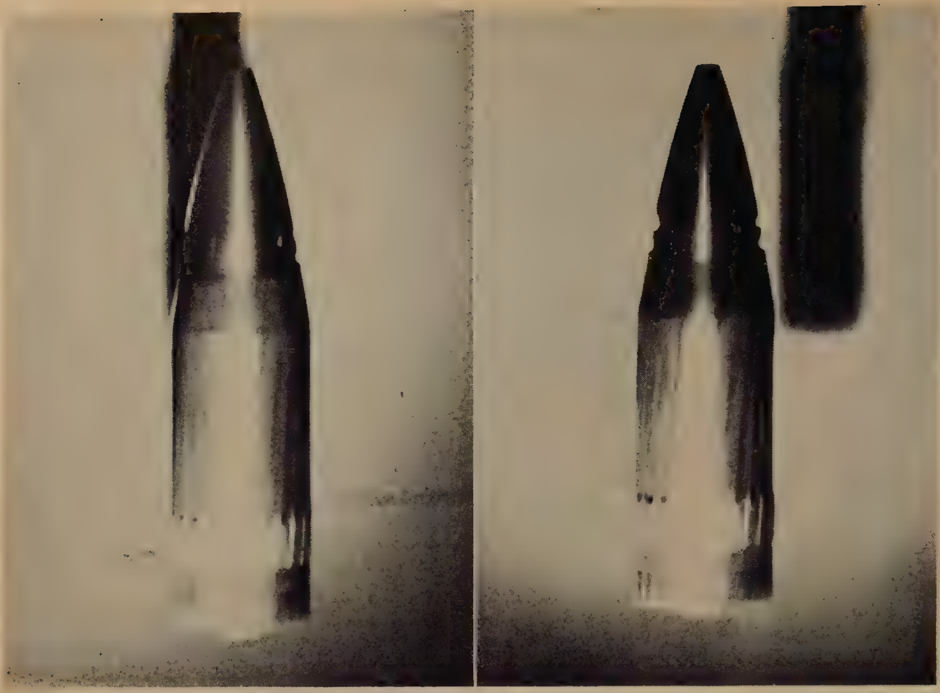

Fig. 6. Stereoscopic view of a three-inch naval shell in flight at 2700 ft per sec. Depth perception can be obtained by viewing each image with one eye. Since the angular separation of the cameras was abnormal, some observers prefer to view the pictures approximately five inches from the eyes, with the eyes deliberately crossed (*Courtesy U.S. Naval Proving Ground, Dahlgren, Va.*)

APPLICATIONS

A brief analysis of the conditions under which Fig. 4 was taken will show this to be a remarkable photograph. In order to obtain as large an image as possible, the camera demagnification was held to 2½:1. The tip of the microtome blade describes a circle of 13.5 inches. Rotation of the wheel at 48,000 rpm resulted in a knife-tip speed of approximately 900 ft per sec. Accordingly, the image of the knife blade at the film plane moved only 0.0086 in. during the two-microsecond duration of flash. Lens aperture was f:8, and synchronization was obtained by means of a specially constructed contactor which does not appear in the photograph.

Fig. 6 is a stereoscopic view of a three-inch 50-caliber naval shell in flight at 2700 ft per sec. The rifle

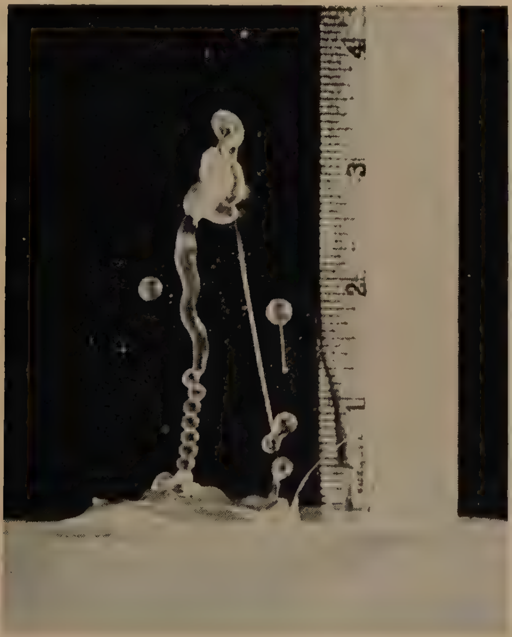

Fig. 7. Oil column produced by pulsing an ultrasonic transducer immersed in an oil bath. Synchronization was manual; shutter contacts initiated the flash

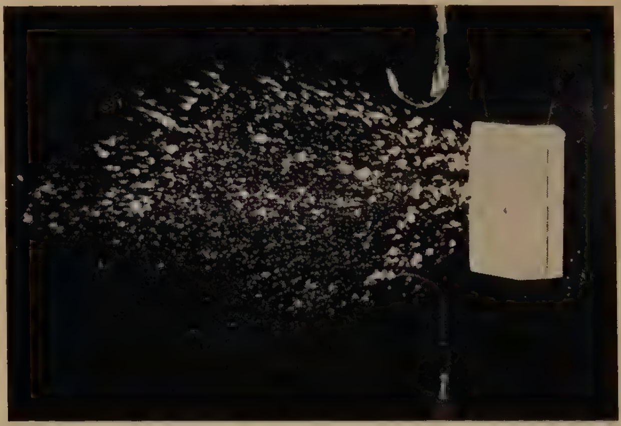

Fig. 8. Rifle fire through a cake of soap. Streaks due to luminescence excited by photolight flash permit study of the paths of particles

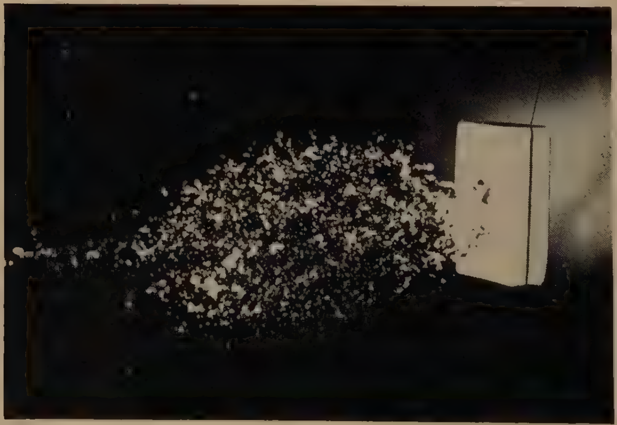

Fig. 9. Rifle fire through soap. Absorption of ultraviolet radiation at the photolight by a sheet of glass improves definition of particles

engraving is clearly visible. The photolight was approximately eight feet from the shell; synchronization was by phototube and time-delay amplifier. With a little practice one obtains depth perception by gazing fixedly at the space between the two pictures while holding the page quite close to the eyes. Some observers prefer to cross their eyes while viewing such photographs.

FIG. 7 shows an oil column produced by pulsing an ultrasonic transducer immersed in an oil bath. Note the interesting bead effect at the base of the column, and oil filaments connecting individual droplets. Synchronization was manual, with shutter contacts used to initiate the flash.

FIG. 8 and 9 graphically demonstrate the effect of fluorescing subjects mentioned earlier. In FIG. 8 a bar of white soap was suspended by threads and a 22-caliber long-rifle hollow-point bullet was fired through it. Synchronization was accomplished by breaking the aluminum foil visible in the picture. Note the streaks in the direction of motion.

A similar experiment was photographed, as illustrated in FIG. 9, with the photolight twice as distant and with one-quarter inch of window glass placed over the front of the flash tube. Note here the absence of streaks and improved definition of individual particles. Synchronization was by crystal microphone.

FIG. 10a through 10c show destruction of some familiar objects either by gunfire or by dropping. Although of no particular scientific value, the pictures are reproduced here to show the versatility of synchronization methods and as a matter of popular interest.

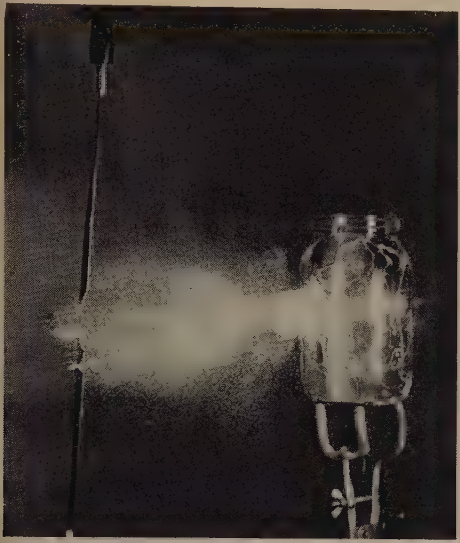

Fig. 10a. Destruction of a glass jar by gunfire. Synchronization was accomplished by parting the foil strip

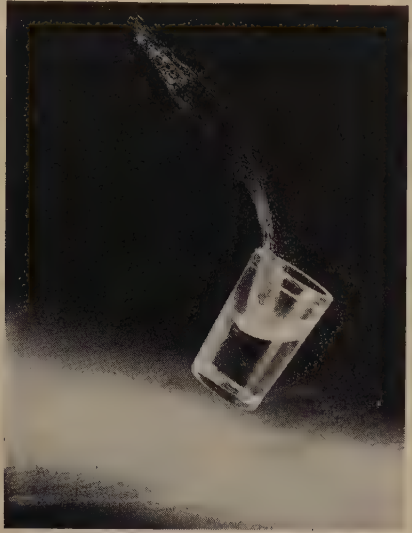

Fig. 10b. Water-filled glass tumbler in midair. The exposure was synchronized manually

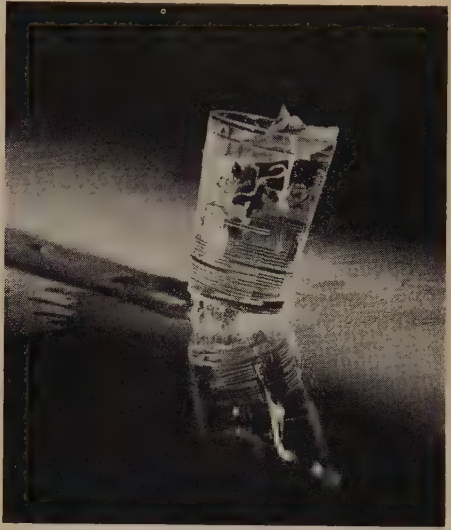

Fig. 10c. A water-filled glass tumbler strikes the floor. The exposure was synchronized by microphone. The glass did not break

CONCLUSIONS

Developed at a time of increasing commercial and military interest in such high-speed phenomena as rocket propulsion, supersonic flight, and ultrahigh-speed gas turbines, the photolight is a highly versatile and valuable tool for the research scientist, the development engineer, and the structural designer. Because it can obtain and preserve data when other methods fail, it is expected to find wide application in the study of high-velocity motion.

ACKNOWLEDGMENTS

The writer is deeply indebted to F. E. Carlson and L. R. Benjamin, Engineering Division, and E. B. Noel, Lamp Development Laboratory, of the General Electric Lamp Department, who by their assistance and co-operation made possible the development and production of the Type FT-130 flashtube. L. E. Gregory, and A. A. Tiezzi, Capacitor Engineering Division of the G. E. Apparatus Department, are largely responsible for the successful development and design of the energy-storage capacitor used in the photolight. The high-speed microtome photographs in the Frontispiece and FIG. 4 were made through the co-operation of E. F. Fullam, Research Microscopist, G. E. Research Laboratory. Dr. J. D. Cobine and H. W. Lord, of that laboratory, and engineers of the General Engineering and Consulting Laboratory too numerous to mention rendered invaluable assistance and advice in the development and design of the photolight and photolight amplifier.

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MEASURING COMMUTATION WITH AN INDICATING INSTRUMENT

Black-band plots as a basis for comparing commutation and brush performance. The advantages and use of a suitable electronic voltmeter for making the measurements

By R. T. LUNDY

Carbon Products Engineering, Apparatus Department
General Electric Company

R. T. Lundy

FOR years, black bands⁽¹⁾ have been used as guides to compare the commutating ability of d-c machines and to set the brushes in the proper place. A black band, as the term is used here, is defined as the number of amperes by which the current through the commutating winding of a machine can be changed without producing sparking at the brush faces. This band width is usually taken at 25, 50, 75, 100, 125, and 150 per cent of rated load. Values are plotted as shown in FIG. 1, the black band being the shaded portion.

In developing new brushes it is necessary to have a fairly fast and accurate way of comparing the commutating ability of the various brushes. The conventional black-band method first was used for this purpose. It was thought, however, that changing the load to obtain these bands disturbed the commutator film, making it difficult to duplicate results. Consequently it was decided to make these comparative tests at full load only, which saves time as well as giving more consistent results. Of course this gives only the band width at full load, not a complete band as shown in FIG. 1. The complete band can be taken if required. Even when the load was held constant, results varied considerably with different observers and with different light conditions. Other variables which affect commutation are: atmospheric conditions (especially humidity), contaminated atmospheres, brush fit, end play of shaft, and commutator surface condition. In developing new brushes it is desirable to eliminate as many of these variables as possible.

With this purpose in view, studies were first made with a cathode-ray oscilloscope and then with an electronic voltmeter and a radio noise meter. Not all electronic voltmeters were found suitable for this service. For example, two that were tried showed very little difference in reading between black commutation and bad sparking. These two voltmeters lacked sensitivity at high frequencies. The meter found to give the best results has a frequency error of less than one percent between 20 cycles and 50 megacycles. This instrument, which has now been used almost daily for two years, is a peak-reading voltmeter calibrated in terms of the RMS value of a pure sine wave. The voltage indicated is 0.707 of the positive peak of the applied voltage. The instrument has five ranges, making it easy to select a suitable scale for the voltage being read. Since the voltmeter is connected across the positive and negative brush studs it has to stand the full d-c voltage of the generator. The instrument as received is limited to 700 volts d-c if the negative lead is connected to the high terminal, and to 300 volts if the positive lead is connected to the high terminal. The voltage is limited by the rating of the 0.006-mfd input capacitor which blocks out the direct current. This voltage rating can be increased by using an external capacitor of the same size with no effect other than raising the lower frequency limit from 20 cycles to about 40 cycles. Specific instructions should be obtained for the instrument when it is to be used on direct voltages above scale reading. Tests were made with the shielded probe of the electronic voltmeter connected directly on a brush stud. This was repeated with the shielded probe in the meter box and with unshielded connections between the voltmeter terminals and the machine. Since little or no difference was observed in the results, the latter and simpler method of connection is now used.

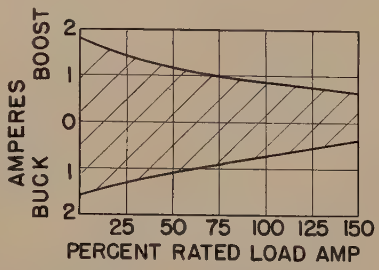

Fig. 1. Typical black-band plot for indication of commutation and brush performance over a range of machine loadings

A conventional compound d-c motor rated 230 volts, 575–2300 rpm, 10/15 hp, 39/58 amp full-load, was used in the evaluation of commutating ability of various brush grades. The tests were all run at 1800

Presented as a paper at the AIEE Winter General Meeting in New York City, January 31 to February 4, 1949.

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

⁽¹⁾"The 'Black Band' Method of Commutation Observation," by T. W. Schroeder and J. C. Aydelott, *AIEE Trans.*, vol. 60, 1941, p. 446.

rpm and approximately 30 volts output. This machine is driven as a generator by a similar direct-connected motor, both being mounted on a rigid steel frame. A thrust bearing was installed to eliminate end play. When first operated, this equipment was located in a large room, but it was soon found that the commutation was affected by changes in atmospheric conditions. The whole set was then moved inside of an altitude chamber(2) where the temperature could be held at 85F with 35 percent relative humidity. The steel shell of the altitude chamber also makes a good shield to eliminate interference when the radio noise meter and the electronic voltmeter are being used. The shield is not essential, however, as good vacuum-tube voltmeter bands have been obtained on a transportation traction motor outside the chamber.

Before a test with a new grade of brush was started, the film was removed from the commutator with a commutator dresser stone and the new test started on a raw commutator. Brushes were carefully sanded to fit the commutator and were finally seated with soft white seater stone. Hourly readings were taken with the electronic voltmeter and then plotted against amperes buck and boost. Amperes buck or boost were changed in half-ampere steps, starting at the middle of the band and going in the buck direction until a voltmeter reading of over 1.0 volt was obtained, then returning to the middle of the band and increasing the boost current to the same limit. From this family of curves (shown in Figs. 2 and 3) taken each day, an average band width at one volt was obtained. The comparison was made at one volt on this machine because the curve had definitely turned up and sparking was evident at this point. To carry the buck and boost current much further caused excessive sparking which damaged the film and then required considerable time for conditions to return to normal.

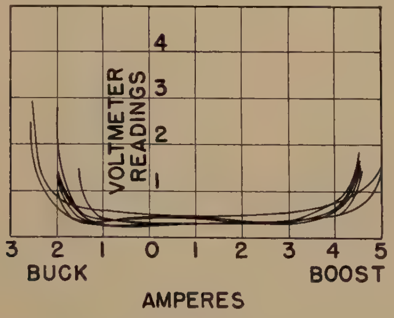

Fig. 2. Representative voltmeter-band plot showing performance of brush No. 6 in Table I. This represents a very good commutating brush

Table I is a summary of test results obtained on five different electrographitic brush grades. Brushes No. 1 and No. 5 were useful commercial grades but not having especially good commutating ability. Brushes No. 2 and No. 3 were commercial grades recognized as better than average commutating brushes, while No. 4 and No. 6 were brushes under development. Brush No. 6 shows exceptionally good commutating qualities. Visible sparking occurred near the bend in the curve in Fig. 2 where the first increase in voltage was read, or at the half-ampere step of buck or boost current immediately preceding it. This has been checked many times while the voltmeter bands were being taken.

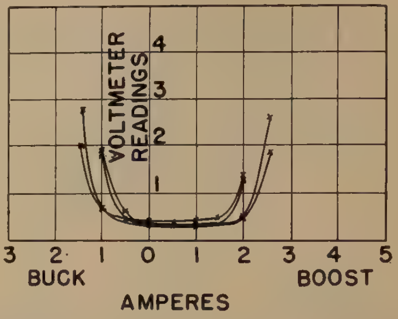

Fig. 3. Representative voltmeter-band plot for brush No. 1 of Table I, a poor commutating brush

A cathode-ray oscilloscope, connected between one brush and a pencil probe about one half commutator bar from the trailing edge of the brush, produces the standing voltage wave shown in Fig. 4. The high peaks occur at a frequency of approximately 1260 per second, which is the calculated slot frequency. The minor peaks between are probably due to the three

TABLE I

SUMMARY OF COMMUTATION TESTS ON ELECTROGRAPHITIC BRUSHES

BLACK BANDS ESTABLISHED BY USE OF ELECTRONIC VOLTMETER

Full-load current, 58 amp; room temperature, 85 F; relative humidity, 35 percent

(Average band width corresponding to a reading of one volt on the voltmeter)

Brush	Amp Buck	Amp Boost	Band Width
1	1.2	2.0	3.2
1	1.2	2.0	3.2
2	1.6	2.6	4.2
2	1.3	2.8	4.1
3	1.3	2.1	3.4
3	1.4	2.4	3.8
4	1.7	2.8	4.5
4	1.7	2.7	4.4
4	1.2	2.8	4.0
5	−0.3	1.8	1.5
5	−0.3	1.7	1.4
5	−0.3	1.9	1.6
6	1.9	4.2	6.1
6	1.8	4.5	6.3

Note: These investigations extended over a period of two months and consisted of fourteen-hour tests, each new test starting with a raw commutator surface.

---

(2) "New Test Chambers for Aircraft Electric Apparatus with Particular Reference to Carbon Brushes," by E. R. Summers and J. F. Settle, *AIEE Trans.*, vol. 63, 1944, p. 1205.

coils per slot in this machine. The sharp points at the tops and bottoms of the wave are caused by sparks when the brush leaves a commutator bar before the current is reduced to zero. The frequency of this spark is high. When the oscilloscope is connected across the brush studs, instead of from one brush to the pencil probe, the pattern is less sharply defined because of the influence of all eight brushes, but the slot frequency is still evident.

Following the commutation tests, an investigation of radio noise generation was made in co-operation with C. W. Frick. With a radio noise meter connected across the brushes readings were taken at the following frequencies: 0.16, 0.2, 0.35, 0.6, 1, 1.5, 2, 3, 5, 8, 11, 15, and 20 megacycles. These readings show a maximum disturbance at 0.35 megacycles, which explains the necessity of using an electronic voltmeter sensitive to high frequencies. For comparison of results with those obtained with the electronic voltmeter, the values plotted are the summation of the readings taken at the different frequencies, converted to an arbitrary scale. This comparison is shown in FIG. 5. It is readily seen that these curves are similar in shape and, as indicated, sparking started near the bend in the curves.

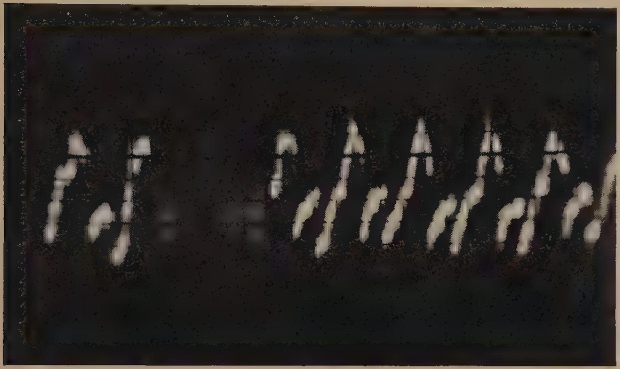

Fig. 4. Indication of sparking by a wave obtained by an oscilloscope. The leads were connected between one brush and a pencil probe placed at a distance of about one half commutator bar from the trailing edge of the brush

Some precautions must be taken when an indicating instrument is used as a commutation meter. Erroneous results may be obtained if the generator supplying the buck and boost current sparks, because the disturbance will follow the wires to the voltmeter. Also, if the machine is loaded by "pump back" or on a line with other generators, sparking of the other machines may be read on the meter. In the tests a resistance load bank has been used to eliminate interference. At one time the generator was separately excited by an electronic current regulator to hold constant load. The current regulator rectified alternating current, supplying pulsating current to the generator field. These pulsations were transmitted to the armature and raised the electronic voltmeter readings over the full width of the band.

If it is necessary to make a test on a generator running in parallel with other machines, it should be possible to block out the high frequency from the other machines by using a filter. Nevertheless there are several reasons for preferring the electronic voltmeter for measuring commutation instead of observing the visual sparking. One advantage is the elimination of the variations in readings due to different observers. This is important as there are considerable differences in the ability of the human eye to detect the first sparks. The local lighting conditions also affect the ability of the eye to see the small sparks. Another important point is that the electronic voltmeter shows sparking on all the brushes with one reading since it is connected directly across the brushes, while with comparable visual observation it is necessary to look at all the brushes at once; and on many machines this is physically impossible.

This more accurate method of comparing commutation makes it possible to study the effect of atmospheric conditions on brushes and machine performance. Besides being useful in evaluating brush performance, the electronic voltmeter should be useful on production tests in setting the brushes in the neutral position, for checking pole shims, and in making sure each machine is within design limits. The requirement of preventing any sudden changes in current, especially at the trailing edge of the brush, has been fairly well taken care of in some machines by the machine designers. In many others current is still flowing between the commutator bar and the brush when contact is broken. This produces a spark, or at least a higher reading of the electronic voltmeter, and may cause etching on commutator bars as well as short brush life and excessive commutator wear. These machines rely on the commutating ability of brushes for their proper operation. The electronic voltmeter is a useful tool in the development and evaluation of brushes with improved commutating ability.

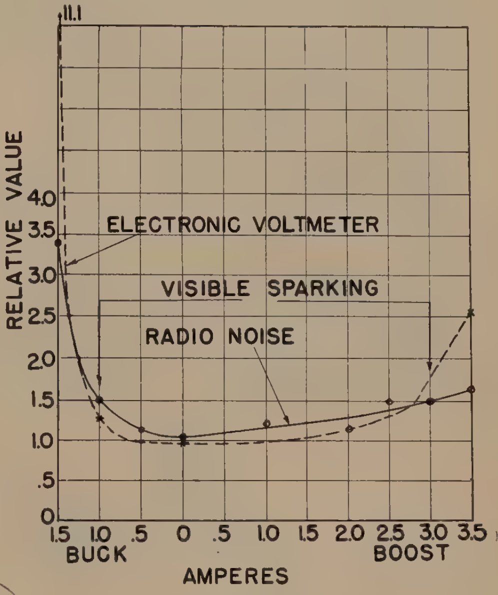

Fig. 5. Comparison of indications of brush performance as shown by radio noise meter readings and electronic voltmeter readings (relative values)

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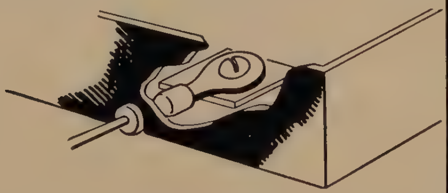

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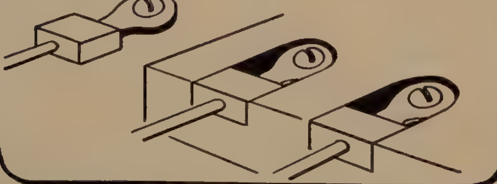

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PROTECTIVE ATMOSPHERES IN INDUSTRY . . Part VII

Methods of carburizing—advantages of gas atmospheres. Carrier gases and what they accomplish. Importance of dew point and other atmospheric conditions in obtaining desired carbon penetration, concentration, or restoration

By A. G. HOTCHKISS and H. M. WEBBER
Industrial Heating Divisions, General Electric Company

FOR maximum wearing qualities, steel surfaces must be suitable for heat-treating to give surface hardness. High-carbon steels, however, which can be hardened are costly and difficult to machine. It is standard practice, therefore, to make gears, pinions, splines, etc. from easily machined low-carbon steel. To obtain the skin hardness required, a so-called case-hardening process must be used. In most processes, the ability to obtain the hardness is dependent on adding carbon to the steel before the hardening treatment; this operation is called carburizing.

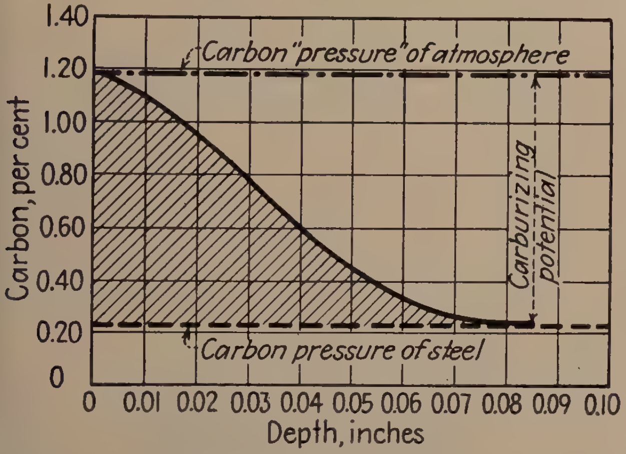


Fig. 55. Typical carburizing curve showing unbalanced carbon concentration from surface to core metal. The shaded area represents the carbon added by carburization

Carburizing materials can be liquids, solids, or gases. All carburizing depends on the ability of the carburizing medium to supply atomic carbon to the metal surface. In this presentation, only the carburizing gases will be considered extensively.

The carbon in iron which gives steel the property of hardenability is that which is in solution. The rate of solubility of carbon in iron is a function of the carbon concentration already in the steel, the temperature, and the carbon pressure or potential of the atmosphere in contact with the steel. Fig. 55 by Kopecki(13) illustrates graphically the typical pattern of the absorbed carbon, and the carburizing potential zone which is the difference between the carbon pressure or potential of the atmosphere and the carbon pressure or potential of the steel itself. The movement of carbon into the steel, as far as the process is concerned, begins to be appreciable at temperatures of 1350 F and above, with normal carburizing temperatures of 1650 to 1700 F being generally used(14).

PACK CARBURIZING

Pack carburizing is the oldest and most nearly foolproof method. It is still used frequently where production is small or where intricate parts must be treated with a minimum of distortion.

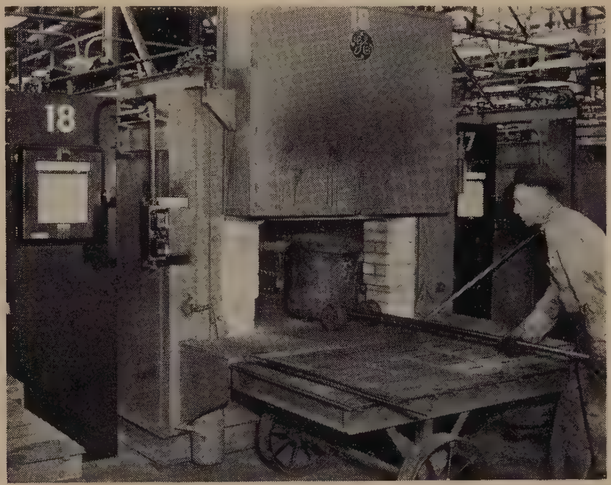


Fig. 56. Box-type electric furnace for pack-carburizing

The process requires the use of closed containers, Fig. 56, generally made of heat-resisting alloy, in which the steel parts are placed and completely covered or packed in carbonaceous materials, such as charcoal mixed with ground bone, or other commercial carburizing compounds. The box is heated in a furnace to carburizing temperatures, held the desired length of time, and then withdrawn from the furnace to cool. The carburizing agent in this method is the nascent carbon monoxide gas which is generated by the action of the carbonate in the mixture. The carbon monoxide

The following will facilitate the location of material published in earlier parts of this serial:

Part	*Issue*	*Figs.*	*Equations*	*Tables*	*Footnotes*
Part I	Nov. 1948, p. 29	1 to 6	None	I and II	None
Part II	Dec. 1948, p. 41	7 to 14	(1) to (18)	III and IV	(1) to (9)
Part III	Feb. 1949, p. 37	15 to 23	None	V and VI	None
Part IV	Mar. 1949, p. 25	24 to 35	None	VII	None
Part V	Apr. 1949, p. 25	36 to 41	None	VIII to X	(10) and (11)
Part VI	May 1949, p. 30	42 to 54	None	XI to XII	(12)

This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—Editor

(CO) decomposes at the surfaces of the parts in accordance with Equation (17) (in a reverse direction) to form nascent carbon which is readily absorbed by the iron to give iron carbide and carbon dioxide. The carbon dioxide reacts immediately with the incandescent carbon which surrounds the iron piece to form fresh carbon monoxide, and thus the reaction continues.

The cost of pack carburizing is necessarily high, because of the amount of labor involved in packing and unpacking, the cost of the compound, the long heating time and the low ratio of weight of work to weight of box and compound.

GAS CARBURIZING

Since carburizing is a surface treatment for steel, it follows that all surfaces must be in intimate contact with the carburizing atmosphere. Also, the atmosphere must be closely controlled to maintain the proper carbon potential. Thus, furnaces for carburizing are especially built to meet these requirements.

Most batch furnaces contain some type of retort, generally made of heat-resisting alloy, in which the work is placed and is surrounded by a carburizing atmosphere. This arrangement excludes air and helps maintain the desired atmospheric conditions. The work is generally supported in such a manner as to permit forced circulation of the atmosphere, thus insuring uniformity of results.

FIG. 57 shows a cross-sectional view of an electrically heated carburizing furnace. It is a cylindrical pit-type furnace with hydraulically operated top cover. The alloy retort is closed at the bottom end and is equipped with a flange at the top, forming a sand seal for the lip of the furnace cover. A smaller cylindrical basket containing the work is placed inside of this retort and supported several inches from the bottom. The circulating fan, which is located in the furnace cover, is fitted with a shroud which acts to direct the flow of atmosphere down along the hot sides of the retort and up through the loaded basket (FIG. 58).

The atmosphere or carburizing gas is introduced through the cover. There is also an exhaust opening in the cover through which excess gas is allowed to escape.

The finished work from such a furnace can be removed from the hot furnace and allowed to air-cool, or it can be placed in an insulated cooling chamber into which a gas atmosphere can be introduced to prevent oxidation and decarburization. Sometimes it is desirable to quench the work directly, in which case it is dumped from the basket into the quench tank, or, if loaded on fixtures, the fixture is lifted from the basket and quenched with the work.

ATMOSPHERES FROM OILS

One of the many forms of supplying carbon for the carburizing process is through the use of oils. Turpentine, linseed oil, bone oil, and specially prepared combinations have been employed. To obtain the atmosphere, it is necessary to vaporize the oil in some manner. This has been done in a small heated chamber, separate from the furnace, by slowly dripping the oil into the chamber where it is gasified by the heat. The generated gas is then piped to the carburizing-furnace retort.

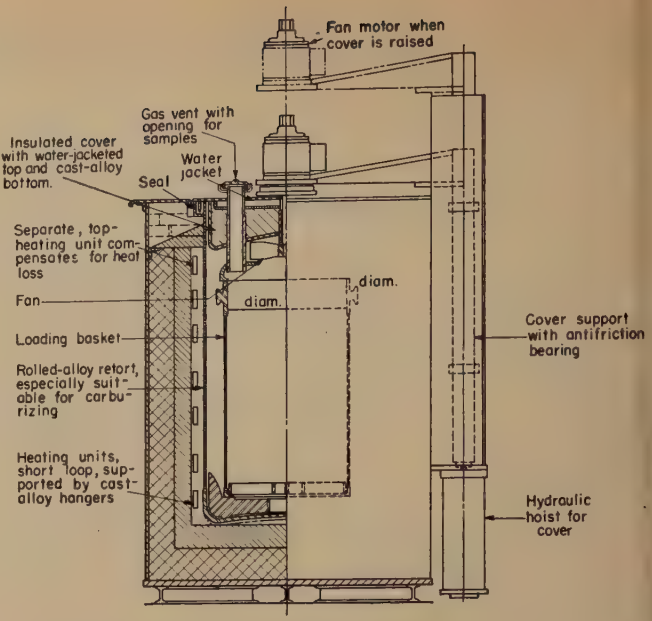

Fan motor when cover is raised
Gas vent with opening for samples
Insulated cover with water-jacketed top and cast-alloy bottom.
Seal
Water jacket
Separate, top-heating unit compensates for heat loss
diam.
Fan
diam.
Loading basket
Cover support with antifriction bearing
Rolled-alloy retort, especially suitable for carburizing
Heating units, short loop, supported by cast-alloy hangers
Hydraulic hoist for cover

Fig. 57. Cross-section of a typical electrically heated pit-type carburizing furnace

Another method is to drip the oil directly into the carburizing retort (using a furnace similar to that just described) where it is distributed by the fan to the hot sides of the retort, vaporized, and decomposed into a hydrocarbon atmosphere.

Control of the atmosphere is accomplished entirely by regulating the volume of the oil being dripped into the retort. To assure the best results, a surplus of carbon generally is formed within the retort and upon the work. This method has in general been replaced by the use of hydrocarbon gases, but is still used where such gases are not available.

HYDROCARBON GASES

In the gas-carburizing process of today, the carbon potential is generally supplied by the use of hydrocarbon gases, such as natural gas or propane (C_3H_8). These gases are suitable for all types of work in any of the various kinds of furnaces now in service. Advantages over the use of oil are greater ease of handling and distribution, and better control of the furnace atmosphere conditions, resulting in cleaner and more uniformly carburized work.

Probably the most widely used hydrocarbon source is natural gas. A typical analysis would be 0.8 percent nitrogen, 83.4 percent methane, and 15.8 percent ethane. Natural gas from any one source has the advantage of being unusually constant in total hydrocarbon content. Its high methane content is desirable, since methane is comparatively stable at higher temperatures and does not crack down readily to form excessive soot (Fig. 9). Equation (18) indicates the carburizing action of methane to produce iron carbide and hydrogen.

The presence of ethane would tend to cause some free soot deposit, but this can be minimized by close volume control. Standard pit-type batch furnaces are generally equipped with flow meters to indicate the gas inlet volume. A typical furnace uses 40 to 50 cfh of undried, raw, natural gas, the flow being largely dependent on the size of the load and tightness of the cover and the retort. It has been found that best results are assured when a pressure of at least 0.10 in. of water is maintained within the retort. With best average operating conditions, tests indicate that the dew point of the atmosphere within the retort can be maintained at zero F or below.

Propane has proved to be a very good carburizing gas and is widely used in areas where natural gas is not available. It is delivered in tanks in liquid form, and is readily transported. For carburizing purposes, propane from the natural gas fields is to be preferred to that made at oil refineries. The latter type contains a high percentage of propylene which under some conditions tends to deposit excess carbon in the form of coke.

The formation of soot and coke from either natural gas or propane gas can be almost completely eliminated when the hydrocarbons are diluted with other gases. This will be explained more fully under the subject of carrier gases.

Propane is now available in almost all regions of the United States, and the ease of handling it is a great advantage. The natural gas propane is very constant in analysis from the start to finish of a tank. When used in a standard pit-type furnace, such as that previously described, propane is fed directly into the retort chamber at the rate of 2 to 4 cfh, depending on the size of the load and of the retort. The results obtained by the use of propane compare very favorably in all respects with those obtained by natural gas.

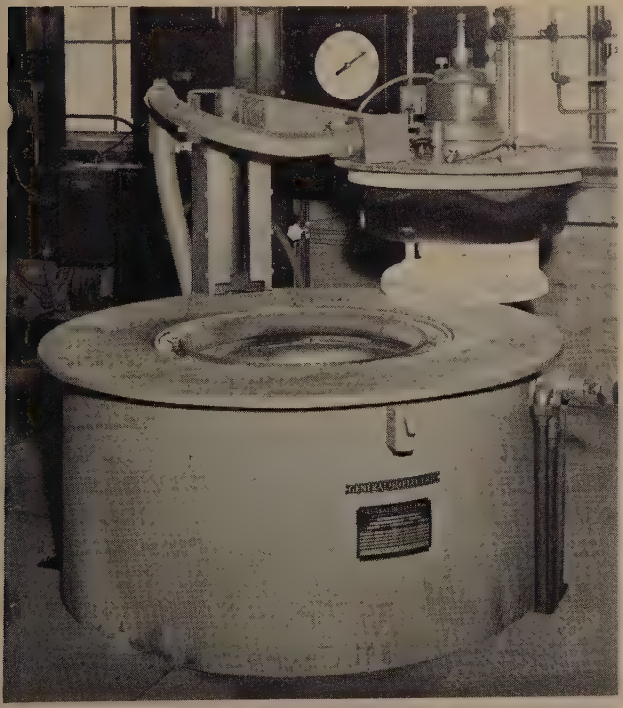


Fig. 58. Pit-type cylindrical carburizing furnace with cover removed just prior to lifting out the work basket

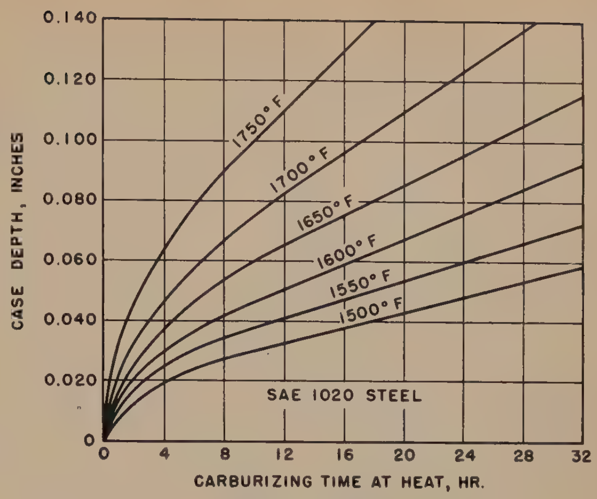


Fig. 59. Time-temperature-penetration curves after Schlumpf(15)

PENETRATION RATE

After steel has reached carburizing temperature and the maximum carbon potential has been attained, the penetration of carbon into the steel has been found to vary directly with the square root of elapsed time. The family of curves in Fig. 59 has been prepared from test runs in a production-type furnace using natural gas as the carburizing medium. These data approximate closely the carburizing rates obtainable regardless of the gaseous medium used. It can be seen that, for a given condition, increased temperatures greatly increase the rate of penetration. It is common practice to carburize in the range of 1650 to 1700 F with a time cycle of 8 to 10 hr.

CARRIER GASES

The offensive soot or carbon formation on the work has been the subject of considerable controversy. At one time it was thought that there was no assurance of continued carburization unless free carbon was present on or near the surface of the work being treated. It was known, however, that excess carbon deposits, especially coke-like formations, could block the surface of the steel and interfere with carbon absorption. In recent years, it had been well demonstrated that free carbon on the surface of the parts is not essential to insure proper or maximum carburizing rates, and that it is commercially possible to bring the products from the carburizing furnace completely clean and free of soot.

To obtain these conditions, control of the atmosphere is maintained through the use of diluent gases of various types which are now commonly called carrier gases. By the use of a carrier gas to maintain an atmosphere pressure within the carburizing chamber sufficient to eliminate air, the rate of available carbon in the form of hydrocarbons can be closely controlled.

It is generally considered desirable to avoid a sharp line of demarkation between the case and the core of a carburized part, since the case may break away or chip at that point. To prevent this condition it is sometimes desirable to change the concentration gradient by means of a diffusion period. This simply means reducing the excess carbon pressure in the atmosphere to permit the carbon already in the surface of the steel to diffuse inward toward the core, and at the same time retaining the desired amount of carbon at the surface. This can be accomplished by stopping the flow of carburizing gas toward the latter part of the cycle. In such a cycle, it becomes evident that the carrier gas must be neutral to the carbon in the case to prevent an undesirable loss of carbon on the surface while the diffusion inward is taking place.

The use of carrier gases which offer almost complete control of the process of carburization has been instrumental in promoting the use of continuous furnaces for this process.(16) Such furnaces are usually of the pusher type, the work being loaded in trays or baskets, which are supported and guided by rails as they are pushed through the furnace.

The pusher-type furnace is built with several intermediate doors throughout its length, which divides the furnace into sections the first of which is a purging chamber. Next is the carburizing chamber where the carburizing gas is added and the desired case depth is developed. Following this, is a shorter chamber where the diffusion cycle takes place by decreasing or omitting the carburizing gas. Lastly, there is an exit chamber where work can be slow-cooled or removed while hot and then quenched.

The continuous furnace is employed generally for large-scale production-line operation, such as in the treatment of automotive and tractor parts.

In accordance with the theory on atmospheres for preventing decarburization, as presented in Parts II, V, and VI, it would be logical to assume that a suitable carrier gas must not contain oxygen, carbon dioxide, or water vapor. However, mention has been made in this Part that the carburizing action is due to nascent carbon monoxide being formed at the surface of the work. With this point in mind, some tests were conducted to determine the results when using combusted fuel gas, partially burned (Ela in Table I), as the carrier gas.

The atmosphere used was that obtained from burning coke-oven gas at an air-gas ratio of 2.25 to 1, of the following analysis: Carbon dioxide 3.3 percent, carbon monoxide 10.9 percent, hydrogen 20.2 percent, methane 1.00 percent, nitrogen 64.6 percent, and a dew point of +75 F.

The carburizing gas, or energizer of propane, was added in small quantities to overcome the decarburizing tendencies of the carbon dioxide and water vapor, and to produce the desired carbon potential. Results from two typical conditions have been selected to indicate here the effects obtained, the only difference being in the amount of carburizing gas being added.

Figs. 60 and 61 show photomicrographs of the cases developed and the carbon concentration vs. penetration of the samples. It can be noted that an increase in propane has increased both the concentration and the depth of penetration, as might be expected. Even though the carrier gas was of a decarburizing nature, a small addition of propane made it very definitely carburizing. Of interest also is the fact that both loads were practically clean and carbon-free, even though there was 5.1 percent methane present with sample B, as illustrated by the data in Table XIII. A slight evidence of free carbon was indication that a greater amount of propane added would have caused definite sooting or excess carbon.

These tests indicate that this type of atmosphere can be used as a carrier gas. If, however, a diffusion cycle is desired, a very close control of propane would be required since the carrier gas described is a decarburizing atmosphere, and a decarburized skin would be present on the surface of the work should the amount of propane be decreased too far.

The most desirable carrier gas then would be one which has a carbon potential of its own, sufficient to prevent decarburization of the carburized surface and permitting the rate of carburization to be definitely controlled by the propane addition.

NEUTRALENE

The Neutralene gas atmosphere (E2a in Table I—partially burned fuel gas with CO_2 and H_2O removed) was described in Part VI as being suitable gas for clean-hardening, normalizing, and brazing carbon steels without decarburization. It would seem logical, therefore, that this should also be a suitable carrier gas for the carburizing process. Curve *A* in Fig. 62 illustrates the carburizing action or carbon potential of Neutralene atmosphere alone. This curve is the result of a single sample treated in this carrier gas with no enrichment by the addition of propane. Curve *B* shows the greater carbon concentration developed when propane was added at the rate of 2 cfh. If, then, a diffusion cycle is desired and the propane is reduced or shut off completely, the carrier gas should not permit the carbon concentration at the surface of the work to be reduced below about 100 points carbon.

The photomicrographs in Fig. 63 give visible evidence of the type of case produced and indicate the slightly higher concentration in sample *B*. These photomicrographs tend to indicate a slightly greater penetration of the carburized case on the *B* sample which is not borne out by the curve. The data for the curves were obtained by taking carbon determinations of successive layers of steel turned from the surface of the test bar.

TABLE XIII

FURNACE AND ATMOSPHERE DATA FOR SAMPLES TREATED IN LOW-RATIO COMBUSTED FUEL GAS ATMOSPHERE*

Sample	Carrier Gas (cfh)	Propane (C_3H_8) (cfh)	Gas Analysis From Furnace					Case Depth (Inches)	Surface Hardness R C
			CO_2	CO	H_2	CH_4	H_2O		
	25	0.0	3.3	10.9	20.2	1.0	+75 F		
A	25	1.2	0.0	16	29.2	1.8	−15 F	0.040	66
B	25	2.8	0.0	15	30.5	5.1	−12 F	0.050	66

*See Fig. 60 and Fig. 61.

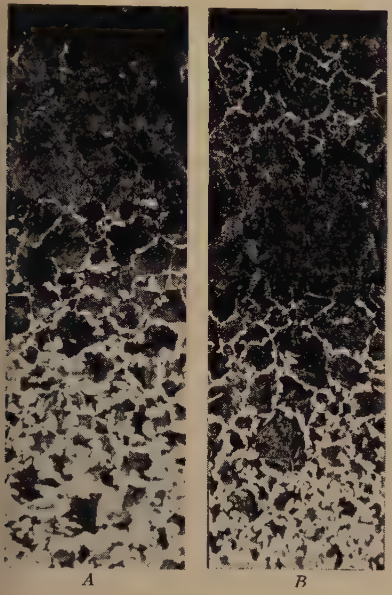


Fig. 60. Photomicrographs (×50) of samples *A* and *B* showing the high-carbon case developed by the treatment illustrated in Fig. 61

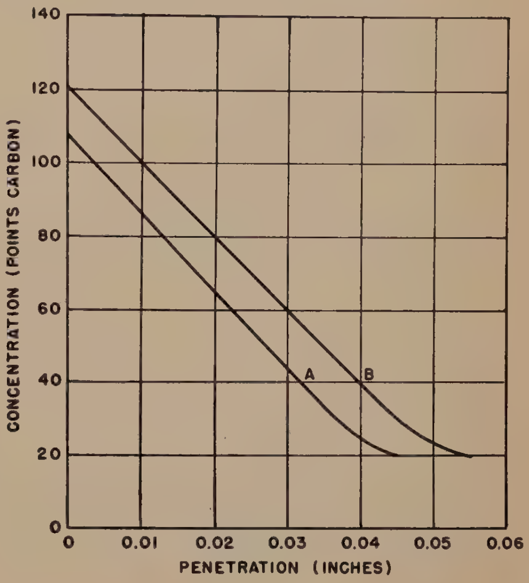


Fig. 61. Carbon gradient of SAE 1020 steel bars carburized at 1700 F for 4 hr in low-ratio combusted fuel gas atmosphere enriched with propane. See Table XIII for detailed data

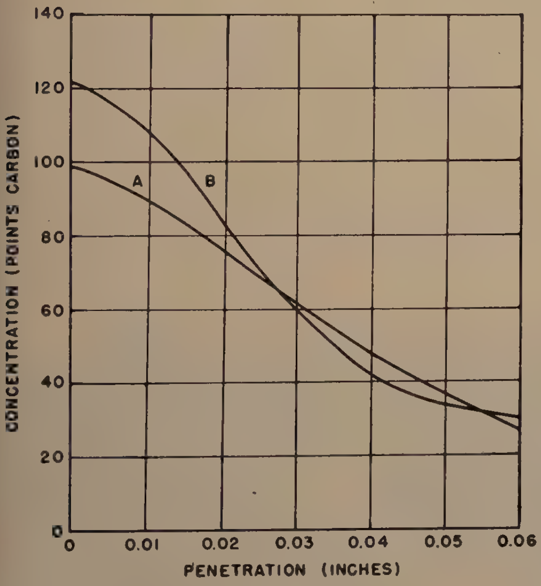


Fig. 62. Carbon gradient from surface to core of SAE 1020 steel bars carburized at 1700 F for 4 hr with Neutralene as a carrier gas. See Table XIV for detailed data

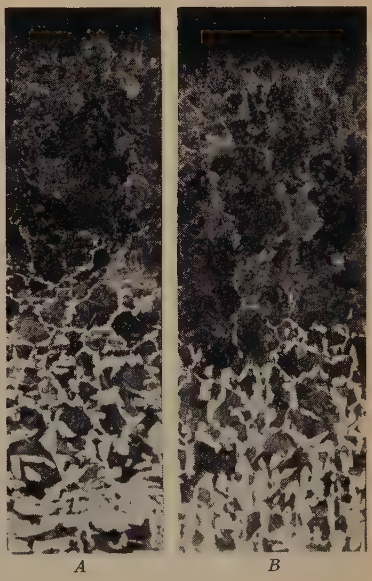


Fig. 63. Photomicrographs (×50) of samples *A* and *B*, showing the carburized case developed by the treatment illustrated in Fig. 62

TABLE XIV

FURNACE AND ATMOSPHERE DATA FOR SAMPLES TREATED IN NEUTRALENE CARRIER GAS*

Sample	Carrier Gas (cfh)	Propane (C_3H_8) (cfh)	Gas Analysis From Furnace					Case Depth (Inches)	Surface Hardness R C
			CO_2	CO	H_2	CH_4	H_2O		
A	25	0.0	0.0	10.9	19.2	1.0	−18 F	0.055	65
B	25	2.0	0.0	10.4	22.9	2.6	−18 F	0.055	66

*See Fig. 62 and Fig. 63.

Table XIV shows that the Neutralene gas for sample *A* contains 1.0 percent methane; therefore, the carbon potential is due to both the methane and the 10.9 percent carbon monoxide present. For sample *B*, the addition of 2 cfh of propane to the Neutralene produces 2.6 percent methane in the retort; however, the parts treated in both gases were completely clean and free from all carbon or soot.

THERMALENE

Another atmosphere described in Part VI as being suitable for preventing decarburization is the catalytically reacted fuel gas called Thermalene. This atmosphere is also a suitable carrier gas and is widely used for this purpose. (Curve *C* in FIG. 67 illustrates the natural carbon potential of a typical atmosphere of this type and indicates about the same carbon potential as that obtained with Neutralene carrier gas shown by curve *A*, FIG. 62.) The increased penetration with Neutralene is probably due to the slightly higher temperature and the presence of 1 percent of CH_4 in the gas.

H. M. Heyn(7) shows similar data for this particular type of carrier gas. He also shows the effect on concentration and penetration when small quantities of methane are added, such as would be required in the carburizing process. The results indicated are almost identical to the similar curve shown here for Neutralene.

CARBON RESTORATION

During the mill processing of many carbon steels, a certain amount of decarburization takes place. Finished parts made from such materials will not be hard at the surface after heat-treatment unless this low-carbon surface is either removed or the carbon is restored to normal. With respect to conservation of material and time, it is becoming increasingly desirable to replace the carbon in such materials. This process is called carbon restoration, or skin recovery. The carbon-restoration process, then, is the exact opposite of carburizing in that the carbon potential of the skin is less than that of the core of the material, and the object is to replace the carbon in the skin until it is equivalent to that of the core. The success of this process is dependent on setting up an exact equilibrium between the atmosphere and the carbon content of the steel prior to its decarburization.

A comparison of FIGS. 55 and 64 will illustrate the difference between carburizing and carbon restoration. FIG. 64 is a typical carbon-restoration curve which shows that the carbon pressure of the atmosphere must be equal to the carbon pressure of the core of the material being treated. The shaded areas represent the carbon added by the two treatments. In carburizing, depth of penetration is a function of time and temperature. In carbon restoration, carbon penetration at any particular point ceases when equilibrium is reached between the atmosphere and the steel, and thereafter time has no effect.

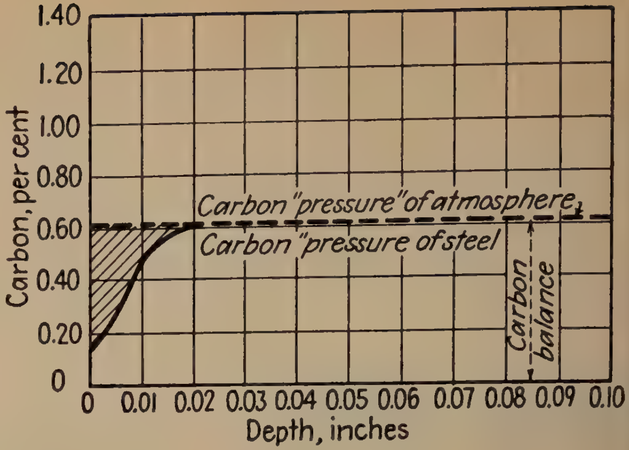


Fig. 64. Typical carbon-restoration curve showing the balanced carbon concentration from surface to core. This treatment adds the carbon represented by the shaded area

The ideal atmosphere condition for carbon restoration requires that the carbon potential of the atmosphere be exactly equal to that of the core of the material being treated. This is especially true of batch-type furnace treatment where parts of the load may be at temperature much longer than the center portion and would thus have time to over-carburize if the atmosphere potential is too high.

FIG. 65 shows a photomicrograph of the thread of a bolt which has been rolled from an SAE-1040 steel rod that had a slightly decarburized surface. This decarburized surface, being soft, has been concentrated at the tip of the tooth; and the light area shows a carbon deficiency along the entire face of the tooth. Two similar bolts were given a carbon restoration treatment in a batch-type carburizing furnace at 1550 F, using a Neutralene atmosphere which analyzed 5.8 percent CO, 6.0 percent H_2, remainder nitrogen, and with a

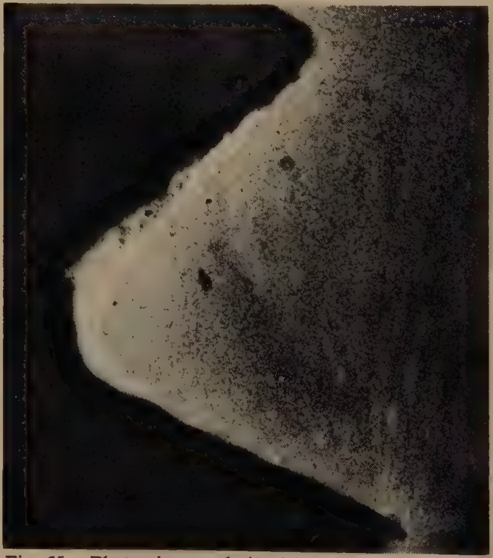


Fig. 65. Photomicrograph (× 50) of a rolled thread of a bolt made from SAE 1040 steel showing decarburized surface

dew point of −20 F. FIG. 66 shows photomicrographs of the two bolts, Sample *A* removed at the end of 2 hr, and sample *B* removed after a 6-hour cycle. These illustrations show a very uniform carbon content from core to surface of thread and no appreciable difference between the results obtained in the 2-hr and 6-hr cycle. This would represent, then, an ideal result from the standpoint of carbon restoration.

Control of the carbon potential of atmosphere has been shown to be dependent on: (a) the concentration of carburizing constituents, such as CO and CH_4, and (b) the concentration of neutralizing (decarburizing) constituents, such as CO_2 and H_2O.

It is generally conceded that the presence of CO_2 in any amount is undesirable since the reactions which take place are then not accurately controllable, especially with atmospheres containing an appreciable amount of hydrogen.

Assuming the absence of CO_2, concentration of water vapor can be adjusted readily, and it has been found to be a very practical medium of control. For instance, increasing the dew point of furnace atmosphere (FIG. 62) from −18 F to +20 F would have the effect of decreasing the maximum carbon concentration from 100 points to about 50 or 60 points of carbon. Penetration would also be decreased.

The dew point control of Neutralene is readily effected by simply by-passing some of the wet CO_2-free gas around the dryer in the proper proportion to obtain the desired furnace dew point.

This method is well illustrated by Leidholm(17) who reported on carbon restoration during the hardening cycle when treating SAE 4330 propeller blades. He found that adjustment of the dew point to about +12 F produced the proper carbon potential.

Since the depth to which carbon restoration is required is in many instances only 0.003 to 0.008 in., the time required is fairly short, and the process is admirably suited for use with the continuous type of furnace. The continuous method also decreases somewhat the necessity for extremely close control, because the work in such cases is usually quenched in oil or water and can thus be timed to leave the furnace when the proper restoration is accomplished. This means that a slightly higher carbon potential in the atmosphere can be used with safety since insufficient time is allowed for the steel to come to full equilibrium with the atmosphere.

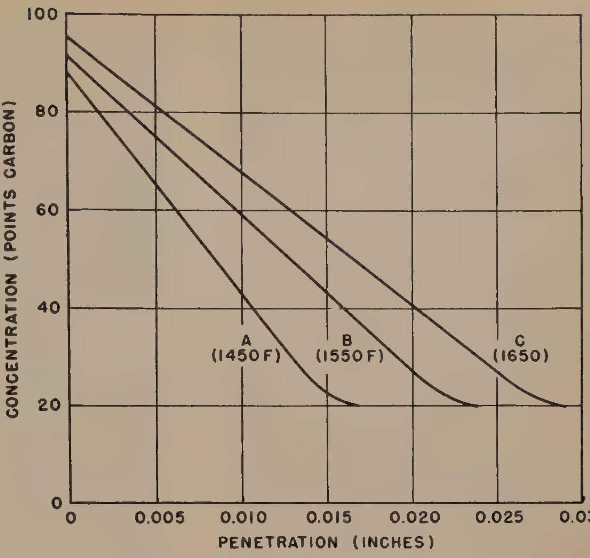
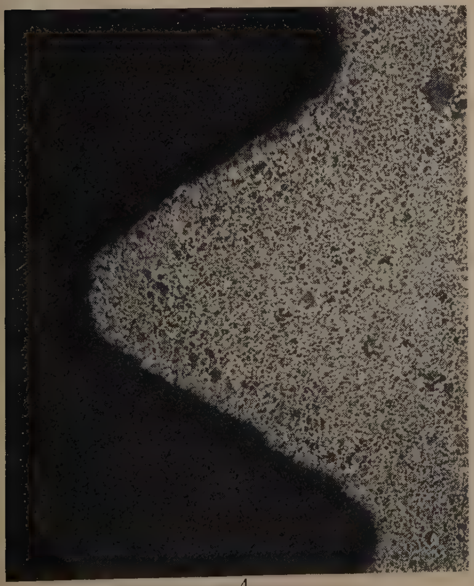


Fig. 67. Carbon gradient of SAE 1020 steel bars treated in a carburizing furnace with Thermalene atmosphere. See Fig. 68 and Table XV

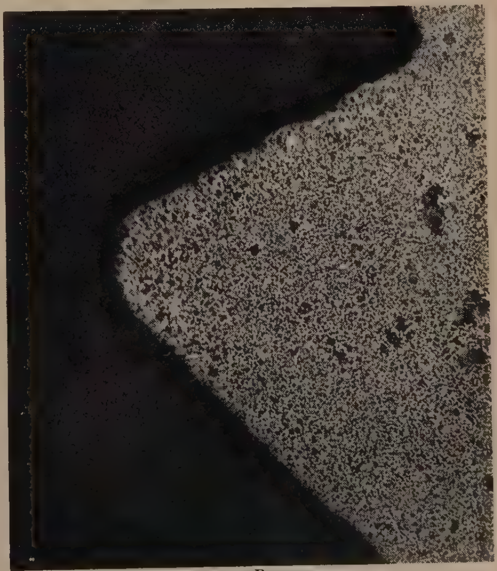
A Thermalene atmosphere is well suited for carbon-restoration work and is rather widely used for this purpose. Again, the controlling constituent is water vapor (dew point). This is well illustrated by Heyn(7) who reports that at 1685 F, a +30 F dew point will produce a carbon potential of 0.50, while a +20 F dew point will raise the carbon potential to 0.75 carbon, and +8 F dew point to 1.10 carbon.



A

Fig. 66. Photomicrographs (× 50) of bolt threads similar to those in Fig. 65 after a carbon-restoration cycle at 1550 F in Neutralene atmosphere

A: 2-hr cycle
B: 6-hr cycle



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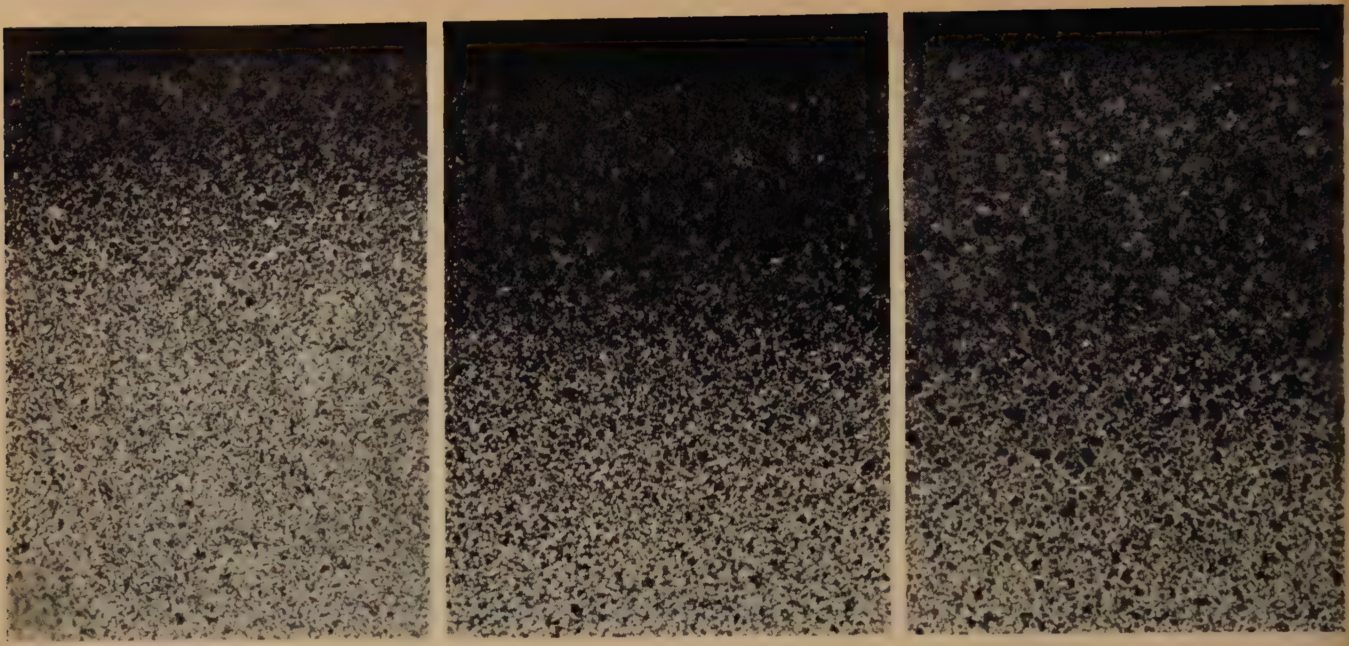

Fig. 68. Photomicrographs (× 100) of SAE 1020 steel treated in Thermalene atmosphere (Sample *A* is shown at the left; Sample *B*, center; Sample *C*, at right). See Fig. 67 showing carbon gradient curves and Table XV for detailed data

The control of the dew point with the Thermalene gas producer is obtained by adjusting the air-to-gas ratio, to maintain the desired setting which will give the required moisture content *in the furnace chamber.* It should be repeated here that it is the dew point in the furnace atmosphere surrounding the work that is important, and that different dew points may be re-

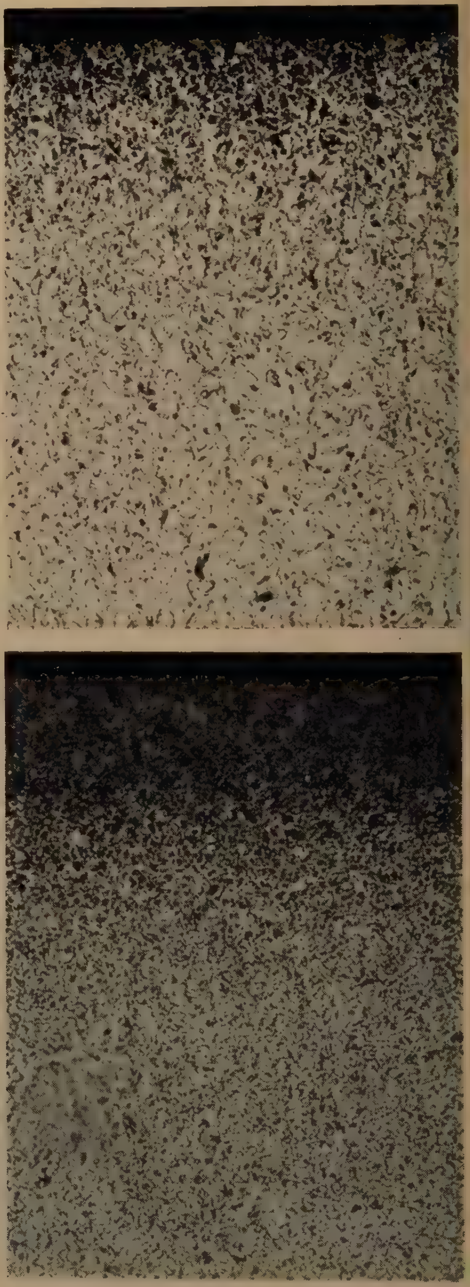

Fig. 70. Photomicrographs of SAE 1020 steel bars (×100) after treatment as indicated in Fig. 69

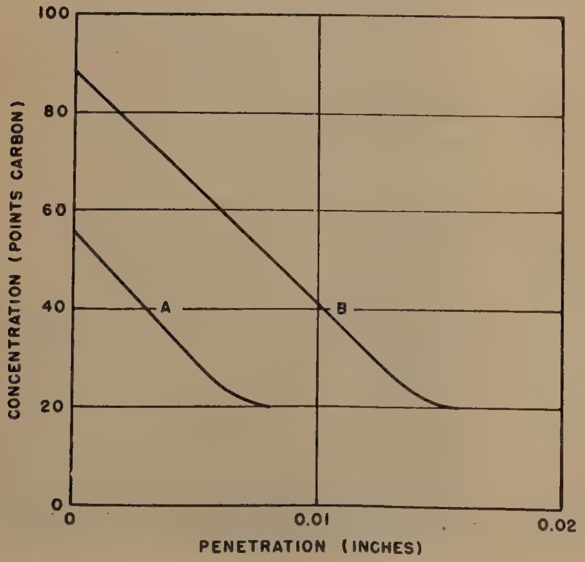

Fig. 69. Carbon gradient of SAE 1020 steel bars treated in a carburizing furnace with Thermalene atmosphere 4 hr at 1450 F (see Fig. 70)

A: Dew point into furnace +40F, out of furnace +60 F
B: Dew point into furnace +10F, out of furnace +34 F

TABLE XV

FURNACE AND ATMOSPHERE DATA FOR SAMPLES TREATED IN THERMALENE ATMOSPHERE*

SAMPLE	FURNACE TEMPERATURE	GAS INTO FURNACE		GAS ANALYSIS FROM THE FURNACE				
	(F)	(cfh)	H_2O	CO_2	CO	H_2	N_2	H_2O
A	1450	30	+10 F	0.0	21.2	48.0	30.8	+34 F
B	1550	30	+10 F	0.0	20.2	47.0	32.8	+33 F
C	1650	30	+ 9 F	0.0	21.6	50.0	28.4	+34 F

*See Fig. 67 and Fig. 68.

quired, depending on other atmosphere constituents and conditions, to obtain the same results as indicated in the preceding paragraph.

FIG. 67 illustrates the effect on carbon concentration and penetration for a given dew point when the temperature of the furnace is varied. It is notable that the change in concentration is slight, but the degree of penetration increases considerably with temperature. FIG. 68 shows the photomicrographs of these samples and visually confirms the results indicated by the curves as obtained by carbon analysis. Table XV lists the data for these tests.

FIG. 69 shows the change in carbon potential which results in a change in dew point for this particular furnace condition. The penetration increases almost directly with an increase in concentration. Again, the results are confirmed by the photomicrographs in FIG. 70. In all the foregoing tests, the work came from the furnace perfectly bright and free from any carbon deposits.

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(*To be continued*)

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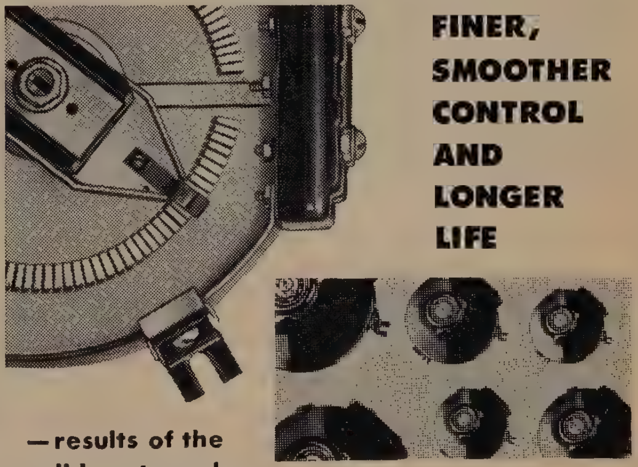

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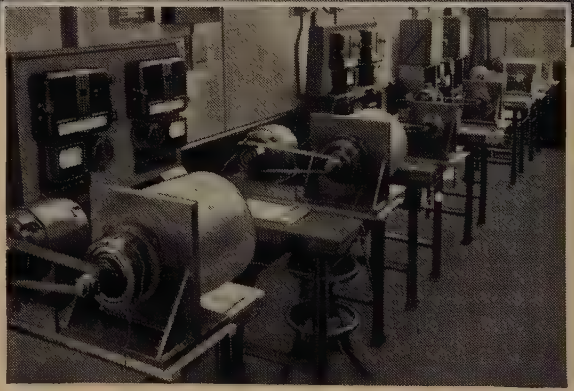

RUNNING TESTS FOR GREASE PERFORMANCE

The test units, illustrated, determine the lubricating properties of "Norma" Stability-Tested greases at elevated temperatures and under actual running conditions. Greases are tested in bearings operated at constant speed and temperature with regular cooling and starting cycles. Bearings are thrust loaded by springs. In other test units, bearings are loaded radially.

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PHOTOTUBE CHARACTERISTICS AS INFLUENCED BY SMALL AMOUNTS OF GAS

Results of research study indicate that good performance stability can be expected by operating the tubes at not over 15 to 18 volts, provided the photocurrent is not high enough to materially alter the voltage applied to the tube

By A. H. TAYLOR

Lighting Research Laboratory, General Electric Company
Nela Park, Cleveland

a. Hadley Taylor

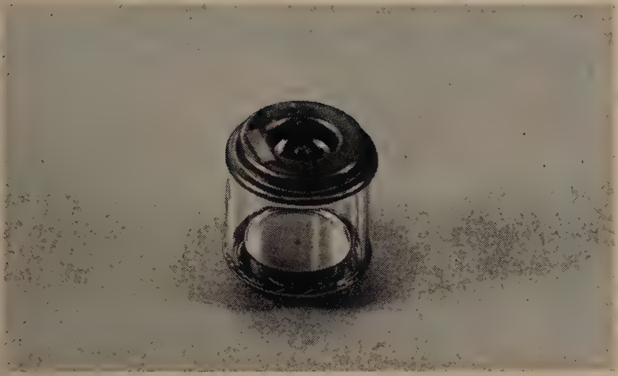

Fig. 1. A small caesium-antimony phototube

DURING World War II many small, cylindrical phototubes (FIG. 1) having cathode and anode at opposite ends of a short glass tube were manufactured for the Government. These were of the vacuum type and had a cathode of caesium on antimony. The spectral sensitivity was approximately as indicated in FIG. 2. While that phototube is now obsolete, a review and analysis of some of its performance characteristics may aid in better understanding some of the variables of other types of phototubes.

Gas in those tubes was one of the principal causes for rejection, since a "gassy" tube might arc when connected to a 135-volt battery. The usual test for gas was a determination of the relative photocurrents at 250 and 135 volts. For those tubes, the photocurrent ratio was not to exceed 1.10 and for most of the good tubes it did not exceed 1.03. However, some tubes which passed the initial tests would later show much higher sensitivity ratios and thus become useless. Much of the research work done by the author during the period of manufacture was directed to a search for test procedures which would eliminate at first inspection those phototubes which might later become "gassy."

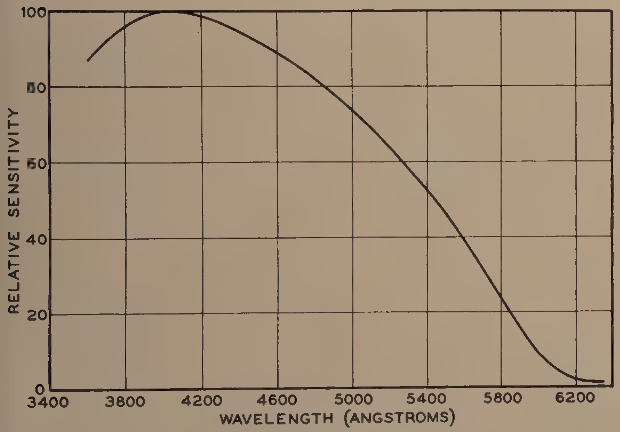

Fig. 2. Approximate spectral sensitivity of the caesium-antimony phototube shown in Fig. 1

TEST EQUIPMENT AND PROCEDURE

The equipment used in testing the response of the phototubes to light included a projector which focused light onto the cathode at an angle of 60 deg from the tube axis. It was possible to illuminate the whole cathode, one half or one quarter of it, or less. Thus uniformity of sensitivity of the cathode surface could be studied. A galvanometer with shunts made it possible to obtain accurate current measurements throughout a wide range.

When a phototube of this type is exposed to light after storage in the dark, its photocurrent usually changes rapidly for a few minutes and continues to change for many hours. This is illustrated in FIG. 3, which depicts results obtained with tubes that would pass the gas-ratio test. The sensitivity of such a tube may be increased 30 to 100 percent by light aging, but the increase is not permanent.

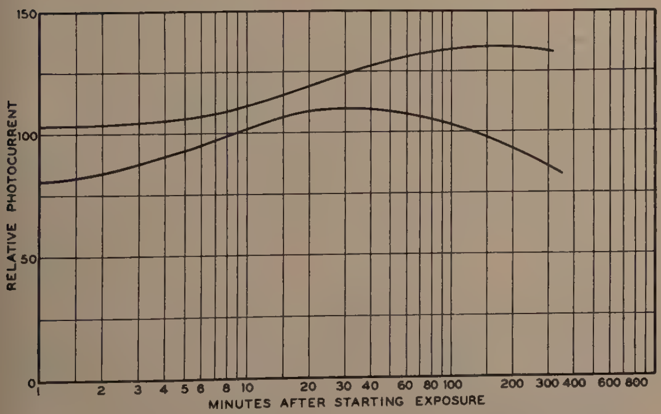

Fig. 3. Change in photocurrent with time for two phototubes, light-aged at constant illumination, with 135 volts applied

Tubes which are gassy and have sensitivity ratios of more than 1.10 at 250 and 135 volts will usually

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This article is so paged that, without mutilating other articles, it can be readily removed for filing as a group of full-size consecutive pages.—EDITOR

begin to *decrease* in sensitivity immediately upon the beginning of light-aging. This is illustrated in FIG. 4, which shows the change in photocurrent with time for a "gassy" phototube aged at 135 volts, 0.75 lumen, and tested at 135, 270, and 400 volts. Its sensitivity ratio at 270 and 135 volts just prior to starting the test was 1.30. At the end of seven hours it had decreased to 1.008, showing that the gas had been almost completely cleaned up.

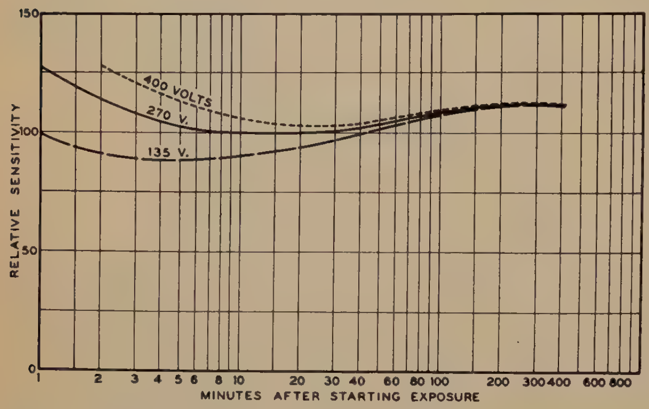

Fig. 4. Change in photocurrent with time for a "gassy" phototube light-aged at 135 volts with constant illumination, the sensitivity being tested at 135, 270, and 400 volts

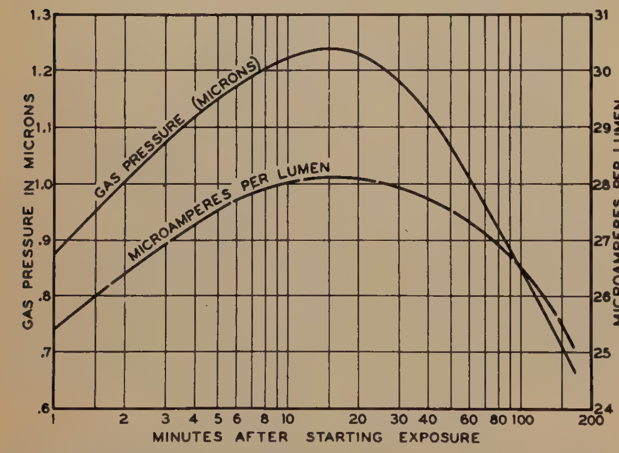

Fig. 5. Changes in gas pressure and sensitivity of a phototube light-aged at 0.2 lumen, 135 volts

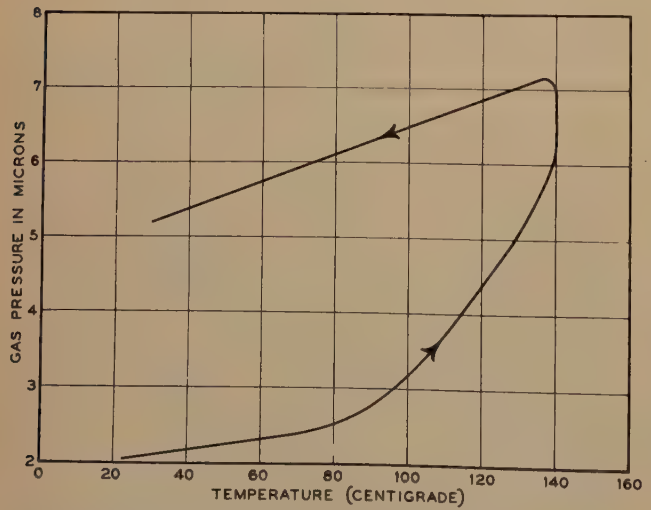

Fig. 6. Changes in gas pressure in a phototube during heating and cooling in an oven

IONIZATION GAGE AIDS THE STUDY

To study more carefully the changes in gas pressure in a tube during light-aging and also its correlation with sensitivity, several phototubes with small ionization gages(1) attached were made up by Dr. Carl Kenty so that the changes in gas pressure could be studied. It was then possible to make simultaneous measurements of gas pressure and sensitivity. Data for one of these tubes are presented in FIG. 5.

It is obviously of importance to determine where the gas goes, if tube quality is to be permanently improved. It is known that excess caesium may act as a getter, and caesium used up in this manner may make an irreversible change in sensitivity. This would be difficult to determine experimentally. One important reason for disappearance of the gas is its absorption by the glass walls of the phototube. Dr. Carl Kenty(2) has shown that clean-up of mercury in a low-pressure mercury lamp may be produced by ion bombardment causing the mercury to be driven into the glass. Apparently most of the clean-up of gas in the phototube during light-aging is produced in the same way. It was found that the gas could be driven out of the walls again by applying a small gas flame to the glass while slowly rotating the tube.

The phototube with attached ionization gage, for which curves were shown in FIG. 5, was placed in an oven and slowly heated to 140 C. It was held at that temperature for about an hour and then the heat was shut off and the oven allowed to cool slowly. FIG. 6 shows the change in gas pressure in the tube during the heating and cooling cycle. During the period of heating from 20 to 70 C little or no gas was evolved, the pressure change being produced by the temperature change. During the cooling period from 137 to 30 C no gas was absorbed or re-emitted, the pressure change being due entirely to the reduction in temperature. This statement can be verified by application of the Boyle-Charles gas law.

The relationship between gas pressure and sensitivity ratio at 270 and 135 volts for one phototube with ionization gage during light-aging is indicated in FIG. 7. The dashed part of the curve represents data for two other phototubes. Data for some other tubes with gas pressures of the order of 5μ give somewhat different sensitivity ratios from those indicated in FIG. 7. This is as might be expected, since the ratio is probably affected by the *kind* of gas as well as by the pressure. Consequently, the sensitivity ratio is only a rough measure of the gas pressure.

PHOTOCURRENT SATURATION

Much information regarding tube quality may be revealed by current-voltage curves. FIG. 8 shows photocurrent as a function of applied voltage for three phototubes illuminated by a projector beam incident approximately 60 deg from the tube axis. When tubes are tested under these conditions, an inflection in the curve nearly always occurs at approximately 15 volts and there is usually a discontinuity in the current at some point between 20 and 30 volts, for gradually increasing voltages. At some point in this range the current suddenly increases to a value which is approximately 85 to 95 percent of the saturation value.

---

(1) "Studies with the Ionization Gauge," by S. Dushman and C. G. Found, *Phys. Rev.* *17*, 1921, 7.

(2) *Journal of Applied Physics* 9, 1938, 765.

Some tests were made using diffused light instead of directional light as furnished by the projector. Saturation curves made with these two types of illumination are quite different, as will be seen in FIG. 9. The complete explanation of these differences is not simple, but it appears to be related to a film of caesium on the tube walls. The explanation seems to be as follows:

During the process of activating the cathode some of the caesium deposits on the glass walls. When the cathode is illuminated, some of the emitted electrons collect on the tube walls, producing a negative charge which tends to limit the current at low voltages, if only a part of the tube wall is illuminated. If there is a thin film of caesium on the tube wall, light falling on it causes it to emit electrons and leave the wall positively charged, thus tending to neutralize the wall charge produced by electrons emitted by the cathode. When a tube is tested with well-diffused incident light, the negative wall charge produced by collection of electrons emitted from the cathode is greatly reduced but not completely eliminated. As a consequence, a tube reaches any given percentage of current saturation at a lower voltage with diffused light than with directional light, since in the latter case only part of the tube wall is illuminated.

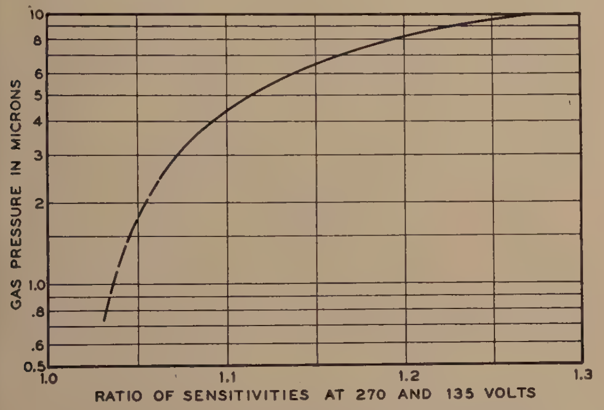

Fig. 7. Relationship between gas pressure and sensitivity ratio at 270 and 135 volts for a gassy phototube during light-aging. Gas pressure *decreased* during aging

That the foregoing explanation is substantially correct has been proved experimentally. A 50-cp lamp having a short straight coiled filament (C-4) was set up with a lens to project an image of the filament onto the phototube wall, the image being normal to the tube axis. With low voltages applied to the phototube, the photocurrent was found to increase as much as 50 percent in some cases, after correction for the photocurrent produced by the filament image acting alone. FIG. 10 shows the results obtained with one phototube, with and without the filament image on the tube wall. The effect is very definite. That caesium on the tube wall is responsible can be shown in another way. A tube having a fairly steep saturation curve when tested with diffused light and reaching 90 percent

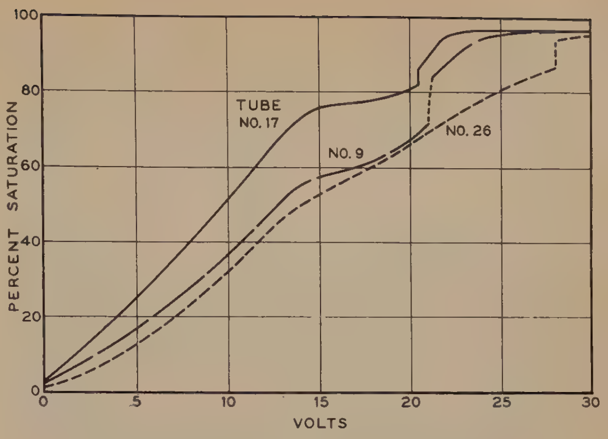

Fig. 8. Current-saturation curves for three phototubes at low voltages and with directional illumination

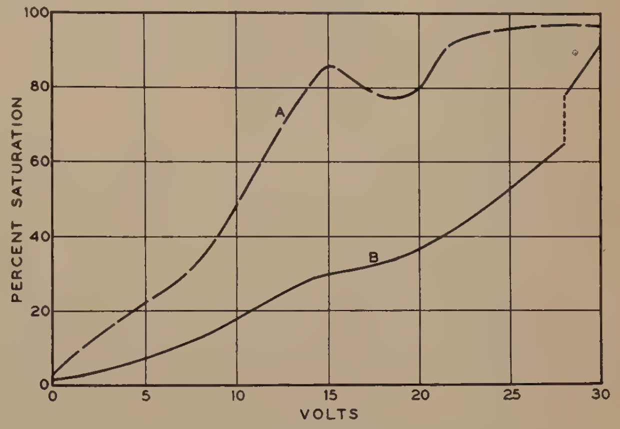

Fig. 9. Current saturation curves for a single phototube tested (*A*) with diffuse illumination and (*B*) with directional illumination. The differences are due to the effects of static charges on the phototube walls

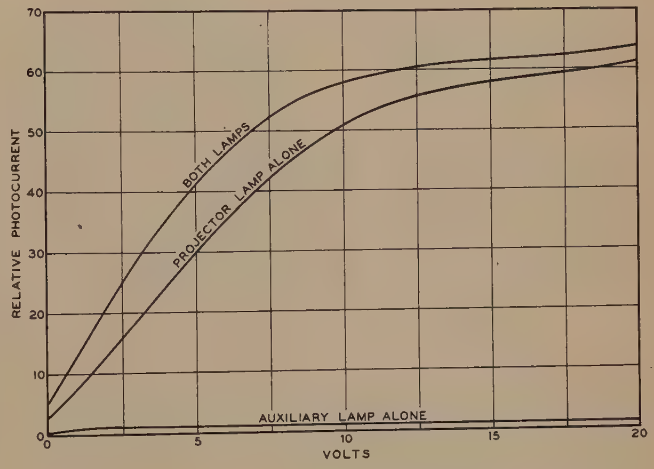

Fig. 10. Changes in current-saturation produced by a filament image focused on the tube wall, to partially counteract the effect of wall charges

saturation at 6 volts was selected for further tests. It was rotated slowly and the tube wall heated by a small hydrogen flame. Tested under the same conditions after heating, the saturation curve was much less steep, reaching 90 percent at 17 volts owing to the reduction of caesium on the walls.

REMEDIAL MEANS

The discovery of the effect of wall charges led naturally to the development of methods to overcome their effects. Fig. 11 illustrates three methods by means of which this may be accomplished. In design (*A*) a coarse-mesh wire gauze cylinder, slightly smaller in diameter than the glass tube forming the phototube, is attached to the anode. It extends almost to the cathode (*R*), thus neutralizing the effect of wall charges. Sketch *B-1* shows a tube having a metal ring just inside the tube wall, attached to the anode, and located half way between anode and cathode. In design *B-2*, two U-shaped metal wires are attached to the anode and extend along the tube walls almost to the cathode. The current-saturation curves *C* and *D* in Fig. 11 represent the approximate extremes encountered in practice in tubes not employing any auxiliary means to offset the effect of wall charges. Curve *A* shows the results obtained with design (*A*), while curve *B* represents results obtained with either construction (*B-1*) or (*B-2*). These results were obtained with a resistance of 5000 ohms in series with the battery and phototube.

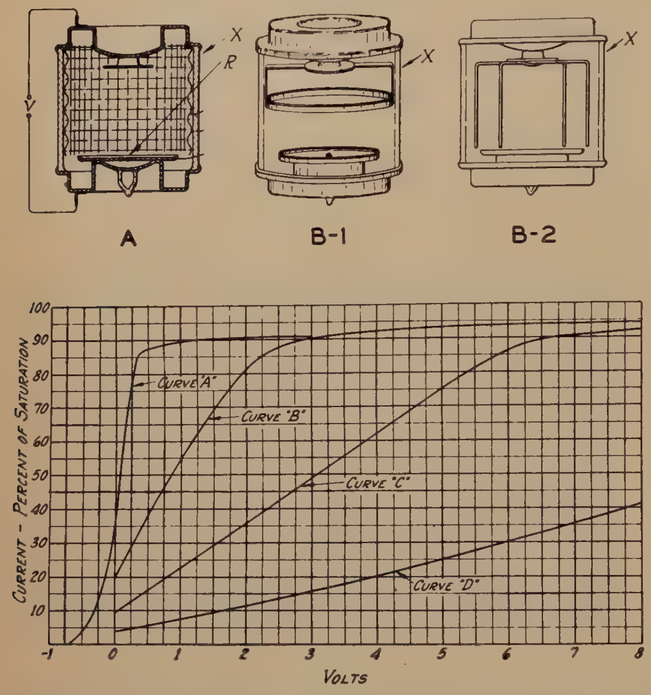

Fig. 11. Three methods (*A*), (*B-1*), and (*B-2*) of neutralizing the effects of wall charges. Curve *A* shows results obtained with method (*A*), and curve (*B*) the results with methods (*B-1*) and (*B-2*). Curves *C* and *D* show the range of saturation curves for phototubes of the ordinary construction

Curve *A* shows 90 percent saturation at 1 volt, where saturation current is defined as that resulting when 135 volts is applied. Current saturation at low voltage has important advantages. Not only is less battery voltage required, but the tube can be operated below 20 volts and thus avoid the undesirable effects of appreciable amounts of gas in the tube, as will be shown later.

Some studies were made to determine the way in which the presence of gas in phototubes produced changes in sensitivity. One method of attack was to illuminate only one half of the cathode and make periodic tests of the sensitivity of the other half. If the light-aging is carried out at 135 volts, the two halves change in sensitivity at approximately the same rate. If the aging is done at 15 volts, the dark half changes much less than the illuminated half. These results indicate that the changes are principally due to ion bombardment of the cathode, occurring at voltages above the ionization potential of the gas. Evidence already cited would seem to indicate that ionization begins somewhere in the range between 15 and 30 volts. A phototube having a low sensitivity ratio (low gas pressure) shows much less change in the dark half of the cathode at 135 volts than one having a high ratio.

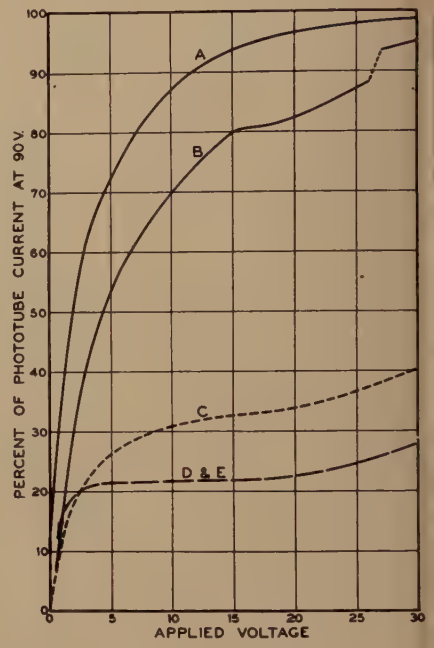

Fig. 12. Current saturation curves for five commercial types of phototubes. Tubes *A* and *B* are vacuum tubes, while *C*, *D*, and *E* are gas-filled. Tubes *A*, *D*, and *E* have tubular bulbs with semi-cylindrical cathodes and axial anodes. Tubes *B* and *C* have long-neck spherical bulbs, the bulb wall being the cathode

Research on these phototubes was terminated before the original source of the gas could be determined. Some evidence indicated that it was not leakage of air into the tubes. Two groups of gassy tubes were light-aged until the gas was cleaned up, then one group was stored in an evacuated enclosure and the other in an atmosphere of hydrogen. When tested several weeks later, both groups had become gassy again.

Since it has been shown that gas is driven into the glass walls during light-aging, it is possible that the glass is the original source of the gas. Possibly a suitable heat treatment at some stage in the fabrication of the phototubes might eliminate or reduce spoilage due to gas.

While it has been shown that gas is one of the factors affecting the stability of these phototubes, it is not necessarily the only one. There is some evidence to indicate that the caesium may migrate to some degree, and thus alter the sensitivity.

PERFORMANCE OF COMMERCIAL TUBES

Photocurrent-saturation curves for one each of five types of phototubes that are now or have been commercially available are presented in FIG. 12. Three of these are of the gas-filled type and two are of the vacuum type. The three gas-filled tubes (*C*, *D*, and *E*) all begin to show the effect of the gas on the photocurrent at approximately 19 volts. The curve of one of the vacuum-type tubes (*A*) does not indicate the presence of any gas. That of the other vacuum tube (*B*) indicates the presence of a small amount of gas, since the saturation curve noticeably changes at 15 volts and a discontinuity takes place in the region of 27 to 28 volts. It appears probable, therefore, that operation of a phototube at not more than 15 to 18 volts might result in better stability, so long as the photocurrent is not high enough to materially alter the voltage applied to the tube through the necessary resistors.

The author has had considerable experience in using phototubes with a monochromator to measure very low intensities of ultraviolet energy. In some instances he found that the photocurrent drifts when the cell is irradiated, especially at wavelengths below λ2800. In the present arrangement of the apparatus a small flashlight lamp, operated at about one half rated voltage, has been placed in the housing which encloses the phototube. This greatly improves the tube's stability.

ACKNOWLEDGMENT

The author wishes to express his appreciation to Dr. C. G. Found for many helpful suggestions he made while supervising this research. Dr. Carl Kenty also gave valuable assistance, especially in the preparation of several tubes with attached ionization gages.

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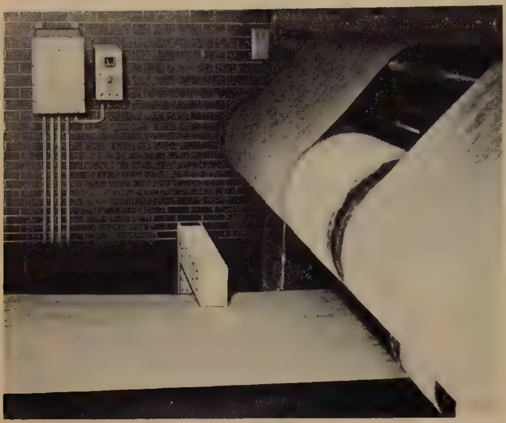

Beta-ray thickness gage installed to monitor resin-impregnated paper from a paper-treating machine. Gage head, control cabinet, and operator's panel are shown

A new instrument has been designed to measure continuously, without contacting or disturbing them, the thickness of sheet materials moving along a conveyor.

Called the beta-ray thickness gage, the instrument measures the amount of beta radiation absorbed by the sheet material being checked. By measuring absorption, the device actually indicates the mass-per-unit area of the material under test, but the equipment can be calibrated in terms of thickness to help operators maintain product uniformity, reduce the amount of rejected material, and save on the amount of raw material used.

The new gage will find application in monitoring the thickness of metal foils, such as aluminum, copper, tin, brass, and steel, being rolled at high speeds. It can also be used with plastics, textiles, rubber, and other sheet materials, especially those which cannot be contacted because of their condition while in processing.

In operation, the beta-ray thickness gage measures the deviation from a chosen setting by registering the beta-rays (high-speed electrons emitted by certain radioactive substances) absorbed by the material under test. The source of beta-rays in the gage is 2.5 millicuries of strontium 90, a radioactive isotope. Those rays unabsorbed by the material passing through the gaging head are gathered in an ionization chamber. An attenuated 90-cycle signal is added in phase opposition to cancel the signal from the ionization chamber. The attenuator voltage, therefore, is a measure of the ionization-chamber voltage, and of the amount of material in the beta-ray beam.

Operating on a power supply of 100-125 volts, 60 cycles, ± 0.3 cycles, power consumption of the gage is about 150 watts. Accuracy is ± 2 percent or better between normal periods of calibration, while drift is not more than one percent per hour after a 30-minute warm-up period. Under normal conditions, calibration need not be made oftener than once every four hours.

Childhood Dream Realized

More than 1800 people had a chance actually to run a diesel-electric locomotive at the 3rd National Materials Handling Exposition in Philadelphia. Visitors were able to start and stop the unit, run it in forward or reverse, blow the whistle, ring the bell, and even sand the tracks. The 25-ton industrial-haulage locomotive was on blocks over simulated rails so that its wheels were free to revolve

New Freezing Temperatures

It can no longer be stated flatly that at a given pressure water always freezes at 32 F; mercury always freezes at −37.7 F; tin always freezes at 449.4 F; or gallium always freezes at 85.5 F.

Research scientists have cooled all four substances far below their so-called freezing points without having them freeze. They have "supercooled" water 71 deg Fahrenheit below its freezing point; mercury, 72 deg below its freezing point; tin 198 deg, and gallium, 125 deg.

Supercooling tests are being conducted by both metallurgists and weather scientists in an effort to learn more about how and why materials freeze. Not only must the temperature and pressure be right for a substance to freeze, it is now explained, but particles about which material freezes, called "nuclei," must also be present. Water, mercury, tin, and gallium have been supercooled by ridding their samples of nuclei, which are usually present in most fluids.

Water below its freezing point is often found in nature, particularly in the form of clouds. The water in supercooled clouds, being without nuclei about which the freezing can begin, does not turn to ice. Methods of producing snow from supercooled clouds are based on putting nuclei into such clouds, causing transformation of water droplets in the cloud to snow crystals.

Metallurgists have made "clouds" of supercooled gallium, tin, and mercury, by dispersing those metals in their fluid form as minute droplets suspended in oil. Some of the droplets may contain nuclei, but since the freezing that begins in them cannot spread to the others through the oil, those without nuclei can be reduced in temperature far below their freezing point without freezing.

In some cases there are limits beyond which substances cannot be cooled without freezing, as nuclei seem to form spontaneously below the temperatures reached. It is believed that in these tests water, and possibly mercury, tin, and gallium, have been supercooled as much as possible.

Electronic Narrator

A unique voice-recording and reproducing machine has been developed which will repeat a message or series of messages an infinite number of times without being rewound or reset.

The "electronic narrator," as the device has been named, uses a continuous loop of magnetic tape which permits approximately two minutes of recording or playback time. This time may be made up of one message or a series of shorter ones. Each recording can be started automatically by any such means as breaking a light beam, stepping on a mat, dropping a coin in a coin mechanism, as in a vending machine or radio, or flipping a switch.

A new message or series of messages can be put on the tape in a matter of seconds merely by inserting the microphone-erase mechanism. The old messages are automatically erased as the new ones are being recorded.

The loudspeaker is separate from the tape-handling mechanism so that it may be located in the most advantageous place. The narrator itself is small enough (about a foot square and six inches deep) to be installed in an inconspicuous space, such as within a vending machine itself. In this type of application the narrator might thank the purchaser or promote the products sold by the machine.

The new device should find countless applications in the fields of advertising, merchandising, and public and industrial safety. A narrator installed beside a grinding wheel might save a great many eyes by warning users to put on their safety glasses.

A new device that records vocal messages for repetition as sales promotion, instruction, or warning

Parking-lot Illumination

An unusual lighting job for safety and convenience was recently installed in the municipal parking lot of Manchester, N. H. The uniformity and high intensity of illumination, clearly shown here, results from the effective application of 16,000-lumen mercury luminaires on ornamental standards

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NEW PRODUCTS: AND WHAT THEIR MAKERS HAVE TO SAY ABOUT THEM

Channel Clamp

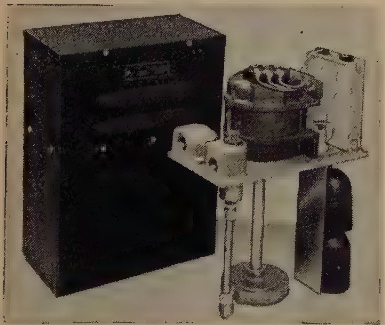
An adjustable channel clamp, No. 177, complements a line of electrical hangers and supports. For supporting runs of conduit from structural channel or angles, where drilling of such building members is either forbidden or too costly, this clamp solves the problem. It rigidly grips various sizes of steel channels or angles and has a load rating of 500 lb, with a safety factor of five.—*The Kindorf Co., 681 Market St., San Francisco 5, Calif.*

Gear Gage

A new gear gage designed especially for shop use can be carried in a tool box or in a pocket. The gage has 16 blades of the following diametral pitches: 4, 5, 6, 8, 10, 12, 14, 16, 20, 24, 28, 32, 36, 40, 48, and 64 in 14½-deg pressure angles.

The teeth are of the correct involute shape. The segment blanks of each pitch are machined in fixtures to conform to the full diameter in accordance with the number of teeth for the full circle. Designers, estimators, and gear users will find the set practical for visualizing the size and strength of teeth or checking the finished gear for diametral pitch.—*George Sherr & Co., Inc., 200 Lafayette St., New York 12, N. Y.*

Disposal Unit



A new condensate disposal unit, Model No. 2, for disposing of small quantities of condensate from air-conditioning equipment. The unit has the following features: fully automatic control, compact rustproof construction, quiet dependable operation, and ball-bearing motor. It is easily adaptable to all standard air-conditioning units.

The unit is equipped with a bronze centrifugal sump-type pump, 1½-gal brass receiver, float-operated switch, check valve on the outlet side of pump, 1/40-hp 3450-rpm single-phase 60-cycle 115-volt totally enclosed ball-bearing capacitor-start motor. —*Eastern Industries, Inc., New Haven 6, Conn.*

Felt Gasketing

Chrome Lock, a specially compounded and impregnated felt containing zinc chromate as a corrosion inhibitor, for protective gasketing or sealing between all types of faying surfaces, such as flanges and lapped or butted joints. Under bolted, screwed, or nailed pressure, the resins traverse within the felt and are also extruded on to the faying surfaces in sufficient quantities to form a positive dam. The resultant seal provides both the exclusion or retention of air, water, dust, and many other materials.

The properties of the gasketing offer several advantages including: rapid application; lower material costs; longer gasket life; positive seal; corrosion prevention; and vibration, shock, and flame resistance.—*Products Research Company, 5426 San Fernando Rd., Glendale, Calif.*

A-c Arc Welders

A new line of a-c arc welders having increased welding range and stepless precision current control. The welders come in 200-, 300-, 400-, and 500-amp models for indoor manual welding; 750- and 1000-amp models for machine and submerged-melt welding; and a special 200-amp model for light-duty job-shop welding. The 300-, 400-, and 500-amp models are offered also in weather-resistant enclosures with idlematic control for both indoor and outdoor operation.

Dual current ranges and increased adjustment overtravel on the machines provide extra-low current range with high maximum short-time output. They are designed with stepless current control, operated by a bearing-mounted current-adjustment crank enabling operator to make precision settings throughout the current range.—*General Electric Co., Welding Divisions, Schenectady 5, N. Y.*

Coaxial Switches

A new line of coaxial switches with solenoid drive for remote control or with manual control for panel mounting. The switches are compact and light in weight, for use in aircraft, radar, and television applications. Single-pole 2-way, 3-way, 4-way, and 6-way switches are available for use with RG-8/U and RG-11/U cable.

The standing-wave ratio is less than 1.25 to 1 at 3000 mc with peaks of not more than 2.0 to 1 at 10,000 mc. Crosstalk attenuation is not less than 60 db to 3000 mc, and not less than 40 db to 10,000 mc.—*Designers for Industry, Inc., 2915 Detroit Ave., Cleveland 13, Ohio.*

Stabilizing Amplifier

A new stabilizing amplifier, Type TV-16-A, for amplifying and improving television-picture signals. It is designed for use in studios and at transmitters as a picture-line amplifier, or as an amplifier for remote-line and radio-relay links. The amplifier will remove low-frequency interference from the signal, stretch and clip supersync, and restore d-c to improve low-frequency response. The equipment can raise a signal as small as 0.2 volts, peak to peak, to a standard picture-line signal of 2 volts.

Some of the electrical specifications on the new amplifier are: frequency response, flat within 5 percent from 0 to 5 mc; input voltage range 0.2 to 3 volts, peak to peak, composite video, 10 percent to 40 percent supersync; output voltage range 1.5 to 2.5 volts, peak to peak, adjustable; also 0.3 to 0.5 volts monitor output. *General Electric Co., Transmitter Division, Electronics Park, Syracuse, N. Y.*

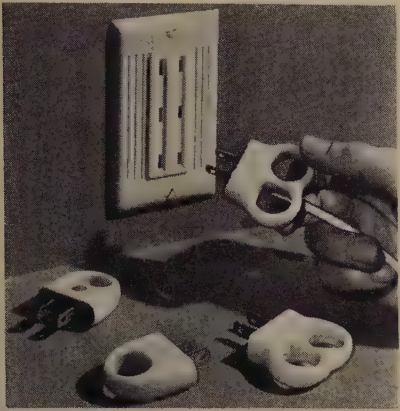
Grinding Attachment

A new high-speed grinding attachment steps up the speed delivered by the No. 2 and No. 4 Haskins flexible-shaft machines at a rate of 2 to 1. This unit is recommended for surface, as well as deep-cavity grinding and polishing operations. It offers means for grinding and polishing welds in hard-to-get-at places, and permits sensitive operation of small rubber- and resinoid-bond grinding wheels up to 2⅝ in. diam.

If the wheel should snag, the molded round belt slips, thereby protecting the wheel and the operator. The belt guard also offers a more convenient hand-hold for more sensitive grinding with less pressure. —*R. G. Haskins Co., Chicago, Ill.*

Plugs

A new type electric plug designed to eliminate difficulty in removal from wall receptacles. The plugs are equipped with finger grips which solve the problem of plugs sticking or being hard to grasp.



Molded with ivory Beetle plastic, an insulating material, the plugs are attractive and durable. This product minimizes wear and breakage on both plug and cord and greatly reduces the danger of electric shock and potential fire hazard from bare wires.—*Thyco Electrical Products Inc., Los Angeles, Calif.*

Unit-bearing FHP Motors

A new line of unit-bearing shaded-pole FHP motors, Type KSP71, designed for use on portable equipments. The motors are available in these ratings: 1/40 hp, 60/50 cycle, totally enclosed; 1/25 hp, 60 cycle, totally enclosed; and 1/15 hp, 60 cycle, open. All ratings are available for 115 or 230 volts and CW or CCW rotation. Each of the three ratings can be used for horizontal or vertical shaft up operation.

Suitable for use as drives for fans, blowers, and small pumps, the new motors have a die-cast aluminum frame. A variety of mountings are available including shaft-end, opposite shaft-end, and resilient-base, to permit equipment manufacturers to select those best suited to their manufacturing facilities or designs.—*General Electric Co., Fractional Horsepower Motor Divisions, Fort Wayne, Indiana.*

Wireway

A new flangeless wireway made in two sizes (4 in. by 4 in. and 6 in. by 6 in.) in 1-, 2-, 3-, and 4-ft lengths. Along the sides are knockouts every 3 in. providing openings from ½ in. to 1¼ in. for easily made connections without costly drilling. The cover, fastened by screws, can be removed easily.

Connections with other sections are made with U-connectors. Interchangeable end closing plates have combination knockouts, accommodating pipes up to 2¼ in. and permitting connections to panel or meter boards without cutting.—*Keystone Manufacturing Co., 23328 Sherwood Road, Center Line, Michigan.*

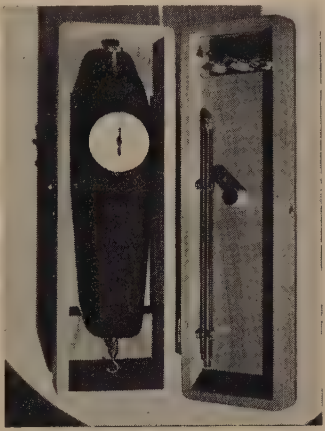
Silicone Insulating Resin

A new silicone insulating resin, No. 9989-1, designed to enable electrical equipment to operate at temperatures as high as 180 C. This insulation has general application for impregnating spun glass and asbestos wire coverings and for binding coils, windings, and other motor, generator, and transformer parts.

The dielectric strength of the resin, as well as its heat and water resistance, enables it to dry tack free in less than 30 min. at relatively low temperature and to be cured to a tough flexible film.—*General Electric Company, Chemicals Division, Pittsfield, Mass.*

Force Indicator

A new force indicator designed to utilize a precision-compensated spring system to give force measurements accurate to ½ graduation or ½ of 1 percent at full scale of the dial indicator. The spring system is composed of three groups: (1) the main compression spring; (2) the compensating extension spring; and (3) the load-transmission rod-centering springs and the springs internal to the dial indicator. The force is applied to the system through a load transmission rod. Movement of this rod deflects the compensated spring system. This deflection is measured by a fully jeweled low-friction dial indicator which indicates the force applied to the system.



The instrument is shaped for easy one-hand operation. Six attachments include: a thrust button, a pulling hook, a conical point-force applicator, a V-notch thrust fitting for lateral rod pressures, a chisel fitting for re-entrant edges and notches, and a 6-in. extension rod. The currently available unit has a 10-lb. capacity.—*Hunter Spring Co., Lansdale, Pa.*

Outside Fluorescents

A new outdoor fluorescent unit called the Post-Lite, that attaches to automobile service-station pipe posts and radiates light in all directions. The unit is available as a full-length cylinder casing for especially beautiful installations, etc., and as a half-round fixture for use on building fronts. Other sizes and types include horizontal lights and ceiling lights for canopies.

The chassis are of heavy aluminum. The inclosing globes are rubber-set and weatherproof. These lighting units are equipped with 40-watt tubes and the globes are 48 in. long; the diameters vary according to models for specific requirements.—*The W. H. Long Co., 61 W. Hubbard St., Chicago 10, Ill.*

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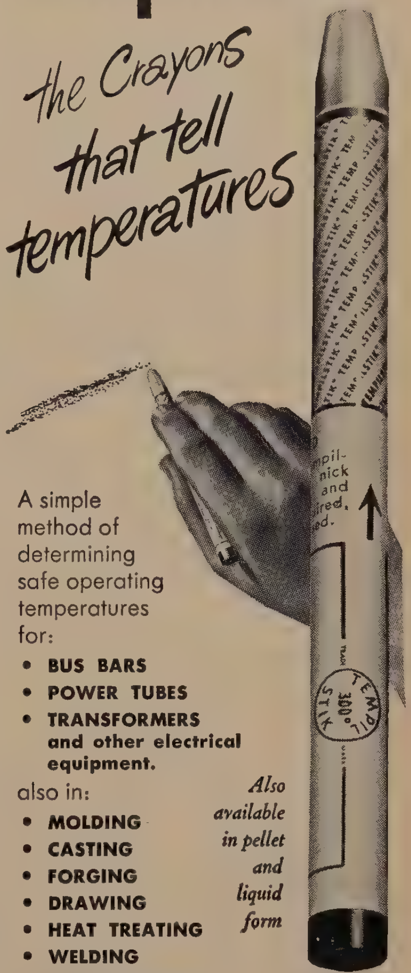

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TRADE LITERATURE

Bearings—A listing of the hundreds of sizes and types of Compo oil-retaining porous bronze bearings immediately available. Data included on bearing formulas, tolerances, loads, and specifications. Sixteen pages. Stock List No. 3.—*Bound Brook Oil-Less Bearing Co., Bound Brook, N. J.*

Beta-ray Thickness Gage—A comprehensive description of the beta-ray thickness gage for noncontacting measurement of thickness. Consideration is given to applications, advantages, theory of operation, accessories and optional features, etc. Thickness range for various materials listed. Four pages. GEC-485.—*General Electric Co., Apparatus Dept., Schenectady 5, N. Y.*

Color Selecting—A color selection wheel, called the Optonic color compass, for quickly and easily determining the proper shades of paints recommended to create better seeing conditions, greater plant safety, etc. Also suggests color programs for painting a wide variety of occasional rooms.—*The Arco Co., 7301 Bessemer Ave., Cleveland 4, Ohio.*

Electrical Tape—Application photographs of No. 33 electrical tape show how it is used in junction boxes, motors, refrigerator units, underground cable, bus bars, etc. The chemical and physical properties of the tape are listed. Four pages.—*Minnesota Mining & Manufacturing Co., 900 Fauquier Ave., St. Paul 6, Minn.*

Insulation—Essential data on size, temperature limits, conductivity, and moisture absorption is given on Rock Cork, a mineral insulation especially valuable for refrigeration service in food and beverage industries. Four pages.—*Johns-Manville, 22 East 40 St., New York 16, N. Y.*

Ni Alloys vs. H_2SO_4 Corrosion—In this presentation on the resistance of high-nickel alloys to corrosion by sulfuric acid, the performance of over 30 different nickel-bearing materials in a wide range of services is analyzed. Numerous tables, graphs, and photographs supply useful information. Forty-four pages. Technical Bulletin T-3.—*International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.*

Prefabricated Feeder—Explains the features and advantages of LVD Flex-A-Power busways used as feeder lines or main feeders. Six actual installation photographs supplement the text. Four pages. Circular 152.—*Trumbull Electric Manufacturing Co., Plainville, Conn.*

Rectifiers—Characteristics, applications, and design factors of selenium rectifiers are covered. Tables supply complete data together with prices. Twenty-four pages. Catalog VC-3000.—*Vickers Electric Division, Vickers, Inc., 1815 Locust St., St. Louis 3, Missouri.*

Substations—Data and electrical and installation diagrams for the following types of rural package substations: Radial with 1 feeder and with 2 to 4 feeders; radial with looping high-voltage circuit; and high-voltage selective for 2 incoming lines. Twenty pages. GEA-5276.—*General Electric Co., Apparatus Dept., Schenectady 5, N. Y.*

Timing Devices—Presents a line of synchronous timing motors and devices, chart drives, and clock movements. Included are photographs and profile drawings; shaft drawings and listing of speeds, voltages, and frequencies; shaft sizes; and specifications as to models and ranges. Twenty pages. Catalog No. 321.—*Haydon Manufacturing Co., Inc., Torrington, Conn.*

Varnish Treatment—A booklet titled "The Zanderoll Process" describes mechanized high-speed production lines for the application of insulating varnish for impregnating and coating armatures, stators, and other electro-magnetic windings. The explanation includes the three types of Zanderoll equipment with illustrations of each. Twenty pages. Bulletin 2263.—*Power Piping Division, Blaw-Knox Co, 1525 Pennsylvania Ave., Pittsburgh 12, Penna.*

Weight Printer—Detailed answers are given to the following questions concerning the Load King scale weight printer: why developed, how constructed and operated, what functions it performs, and what models to use for particular jobs. Tables list full printing capacities, and drawings show dimensions for space planning. Twelve pages. Bulletin P1135.—*Yale and Towne Manufacturing Co., Philadelphia Division, Philadelphia, Pa.*

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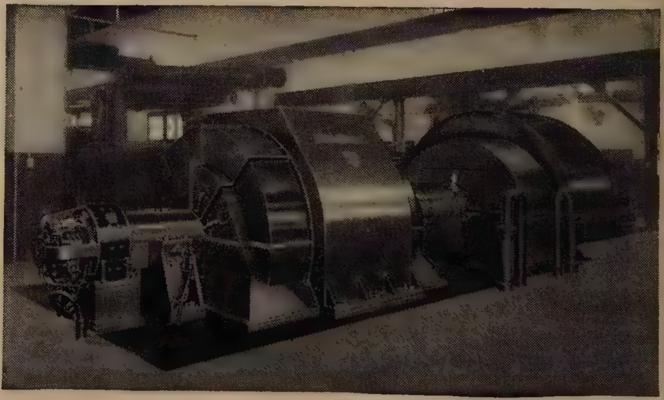

9,000 hp Synchronous Motor, manufactured at C-G-E Peterborough Works, driving a centrifugal compressor at a large Canadian nickel mine.

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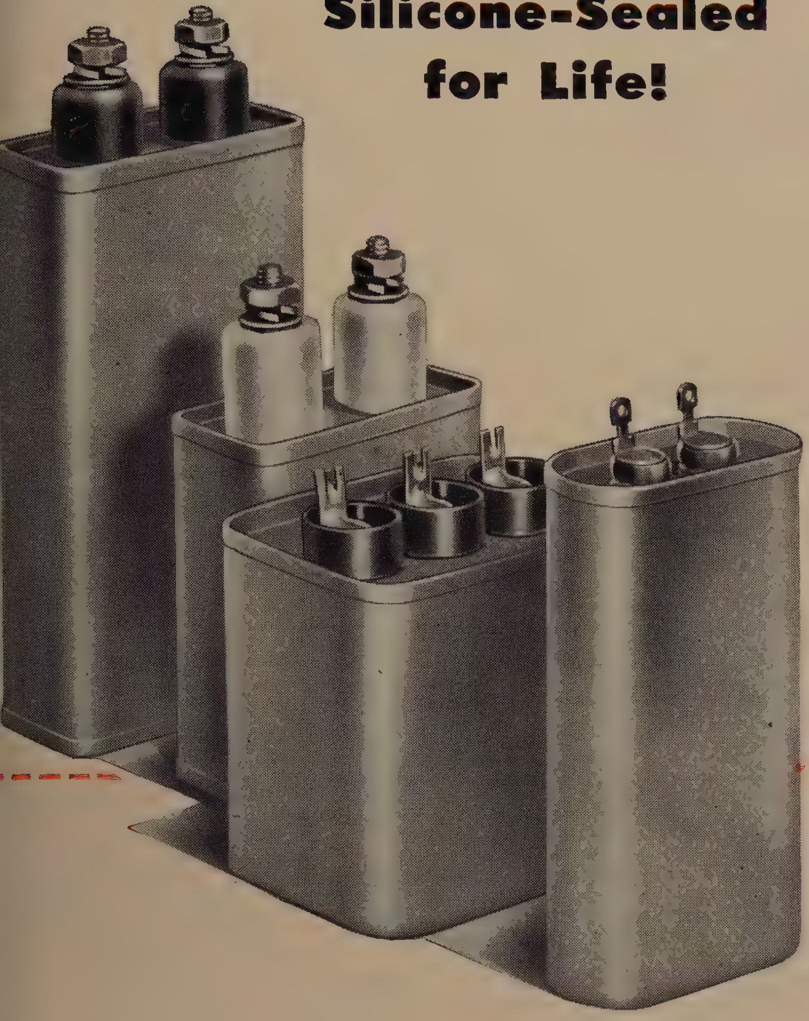
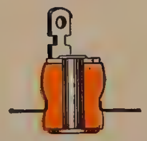


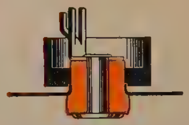
Silicone—the amazing new synthetic—made headlines when General Electric brought it out during the war. It's news again today—for G.E. has now made Silicone bushings and gaskets a *standard feature* of all its specialty capacitors up through 5000 volts.

This means that your new G-E capacitor is sealed positively, permanently—for maximum life. For Silicone seals by compression alone, without the use of contaminating adhesives. It will never shrink, loosen or pull away—it remains elastic at any operating temperature a capacitor will ever meet. Moreover, it is impervious to oils, alkalies and acids, and its dielectric strength is permanently high.

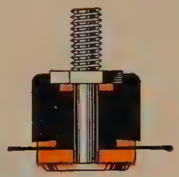
This exclusive G-E feature—with the use of highest grade materials, with strictest quality control and individual testing—make General Electric capacitors finer and more dependable than ever before. *Apparatus Dept., General Electric Company, Schenectady 5, N. Y.*



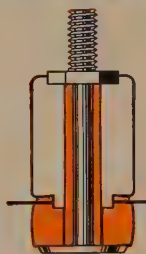
Silicone bushings used with capacitors 660-v a-c, or 1500-v d-c and lower.



Silicone bushings and plastic cups used with capacitors 660-v a-c, or 1500-v d-c and lower.



Silicone gaskets and plastic stand-offs used with capacitors rated 2000-v d-c and lower.



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BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW *for domestic delivery; none sent on approval.)*

PRINCIPLES OF ELECTRIC AND MAGNETIC FIELDS

Warren B. Boast—Harper & Brothers, New York. 1948. xiii + 405 pp. $4.75.

Here is a book that bridges the chasm between elementary circuit theory and the full comprehension of electric and magnetic fields. It is not for the beginner, nor is it for the high-powered mathematician, but it is for the person who would like to understand thoroughly the concepts and behavior of electric and magnetic fields. The book is divided into three parts: electric fields; magnetic fields; and the practical aspects of electric and magnetic fields.

It begins with the behavior of electric fields and explains the associated concepts, such as force, capacitance, potential gradient, and polarization. The author ends this section with an excellent treatise on the method of images.

The section covering magnetic fields begins with the magnetic effects of electric charges in motion, and continues with this thought through the more complex concepts of magnetic fields.

In part three is given a wonderful treatment of flux plotting, graphic construction, and the techniques involved. A small section on permanent magnets and transients in linear systems is also included.

The author unfolds his thoughts in a logical and crystal-clear manner. Throughout the book, there is an abundance of well-chosen and descriptive figures and diagrams to help the reader visualize the theory.

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PRACTICAL SPECTROSCOPY

George R. Harrison, Richard C. Lord, and John R. Loofbourow—Prentice-Hall, Inc., New York. 1948. xiv + 605 pp. $6.65.

The spectroscopy laboratory at Massachusetts Institute of Technology became well known under the direction of the senior author of this book, not only for the contributions that came from there—most notable perhaps are the M.I.T. Wavelength Tables—but also for the stimulation given to outside workers through the Summer Conferences in Spectroscopy held there for many years before the war. In this book Professor Harrison and two of his associates at the M.I.T. Spectroscopy Laboratory have written a text based on their extensive experience and knowledge in the field—one as physicist, one as chemist, and one as biophysicist.

It is in every sense a practical book, telling where a spectroscope is useful, exactly what can be expected of it, what type of spectroscope to use for a given purpose, and how to use it properly. It mentions all the tricks and techniques for dealing with most of the problems that arise in spectroscopy, whether in the ultraviolet, visible, or infrared. The authors fortunately chose to make the book exhaustive rather than comprehensive, leaving the reader to follow references to the literature for further detail. They have attempted to cite both the original and the most up-to-date treatment of the topics involved, in addition to giving general references. The book will certainly become one of the most valuable reference texts for those concerned with any application of spectroscopy.

F. J. STUDER

SCIENTIFIC FOUNDATIONS OF VACUUM TECHNIQUE

Saul Dushman—John Wiley & Sons, Inc., New York. 1949. xi + 882 pp. $15.00.

One of the first authoritative treatments of problems in the field of high vacuum appeared as a series of articles in the GENERAL ELECTRIC REVIEW during 1920-1921. Dr. Dushman's early publication was based on his own extensive work in the field and was quite logically implemented by the developments then under way at the General Electric Laboratory. Dr. Langmuir and his associates were constantly faced with high-vacuum problems, and it was not until these were solved that all the myriad of electronic devices such as x-ray tubes, television tubes, etc., became possible. As a matter of fact, the first interest in an application of high vacuum was initiated by the incandescent-filament vacuum lamp.

The title of Dr. Dushman's book is in keeping with the contents. Here in one volume we now have a very thorough treatment of the scientific foundations of high-vacuum practice. The book is written to be of maximum value to the worker concerned with research and development where vacuum phenomena are encountered, with less emphasis on the engineering and economic aspects of industrial processes.

Complete data are given for computing the flow of gases and vapors according to requirements of the vacuum engineer. The theory of flow and gas viscosity is treated with great clarity and thoroughness, on the basis of fundamental concepts of kinetic theory.

An excellent review of the development of the diffusion pump also includes typical operating data for the most recent commercial units. All possible methods for the production and measurement of low pressures are described in detail with specific information concerning the most recently developed instruments as currently employed by research workers and industry. Here for the first time is given a review of modern developments in leak detection.

A substantial portion of the book is devoted to three chapters, totaling 266 pages, describing the interaction of gases and vapors with solids. Here is a highly exhaustive review of the theory, with available data on gas and vapor absorption and absorption under varying conditions of pressure, temperature, etc.; and with a variety of materials such as glass, cellulose, charcoal, powders, and metals. Problems of gas evolution and diffusion of gases in solids under vacuum conditions are treated in detail. In the metals field, questions of gas content are again covered, with particular emphasis on gas diffusion and occlusion and the influence of such problems on vacuum melting and degassing.

Problems of evaporating metals and alloys are particularly well covered from a theoretical viewpoint, although the development of such operations on an industrial scale is not considered. A brief review of problems of free-energy calculations is included together with a discussion of typical reactions of metals, including data on thermal reduction of compounds and oxidation rates.

With the exception of patent references Dr. Dushman's book contains by far the most complete and up-to-date review of all prior art in the field that has yet been published. No one is better qualified to comment on work in this field, and it is doubtful whether Dr. Dushman needed to go to such extremes to mention the work of others, regardless of the importance of their work.

Certainly no library could afford to be without this publication, even if it were judged on its reference value alone; and it is a most welcome and long-awaited addition to the desks of all research men or engineers engaged in the growing field of high vacuum.

RICHARD S. MORSE

BIOLOGICAL REACTIONS CAUSED BY ELECTRIC CURRENTS AND BY X-RAYS

J. Th. van der Werff—Elsevier Publishing Co., New York. 1948. xii + 203 pp. $5.00.

This book is not, as its title might seem to imply, a descriptive review, but rather a thorough treatise which, through extensive use of mathematics, attempts to explain by a common principle many diverse phenomena which are observed in studies of nerve physiology and radiology. Since previous work in these fields has usually been at a more empirical level, readers familiar at once with nerve-stimulation phenomena, radiology, and the solution of differential equations will be rare, and the book makes difficult reading for anyone lacking in knowledge of any of these fields.

A living organism, according to van der Werff, must not be treated as a static system, in which changes occur only in response to stimuli from without. Even a simple cell is a balanced dynamical system in which constructive (assimilation) and destructive (dissimilation) processes are continually occurring. External influences (viz., electrical stimulation or irradiation by x rays) cause shifts in the equilibrium between these processes. The effects of stimulation will not, in general, be instantaneous —latency times are involved which ordinarily will be different for assimilation and dissimilation processes; also, one can expect that externally applied disturbances will have unlike effects on the rates of various types of processes.

These considerations are elaborated by setting up a general differential equation of the first order applicable to all metabolic processes and applying it in extensive detail to the explanation of all phenomena observed in the two fields. Many effects which hitherto have been thought indicative of some rather mysterious mechanism for recovery, which an organism calls into play as soon as damage is done to it, appear quite logically as necessary results of shifts in equilibrium between processes which continually occur throughout the life of the organism.

The author does not identify the "biogenic" and "radiosensitive" substances to which he applies his theory. A full explanation of these processes will require a vast amount of work, but this theory should be a most significant step forward and most valuable as a guide to future research. Radiologists should note the prediction of new effects which may be expected with peculiar time-distributions of x-ray intensity.

This book will be worth extensive study by workers in these now-unified fields. It is not suitable, however, as an introductory text for one not familiar with at least some phases of radiology or physiology.

George C. Baldwin

Radio Engineering, Vol. I

E. K. Sandeman—John Wiley & Sons, Inc., New York. 1948. xxiv + 775 pp. $6.50.

This is the first book of a two-volume set originally intended for maintenance engineers with the British Broadcasting Corporation. The first nine chapters are designed primarily for beginners in radio who have a working knowledge of algebra and logarithms. Here Mr. Sandeman presents the fundamentals of electricity, vector notation, a-c networks, harmonic analysis, and thermionic tubes, with particular emphasis on their radio applications.

This section compares very favorably with the numerous books having the same objective already in print. It includes numerous illustrative examples and problems to be worked by the reader, a rather complete treatment of RF resistance, and many valuable charts and design curves not readily available elsewhere, which should interest the practicing radio engineer as well as the beginner.

The remainder of the book is devoted to the major components of a transmitter: amplifiers, oscillators, modulators, transmitter types, aerials, and aerial-coupling circuits. The presentation stresses the physical picture and practical application; it includes step-by-step design and lining-up procedures. This part of the book also contains many useful charts and curves and is especially noteworthy for its treatment of class C amplifiers, inverted amplifiers, neutralization, and multivibrators.

The two-volume set should be valuable to beginners and radio hams. It offers to the experienced radio engineer a handy reference and maintenance guide and a picture of British broadcasting practice.

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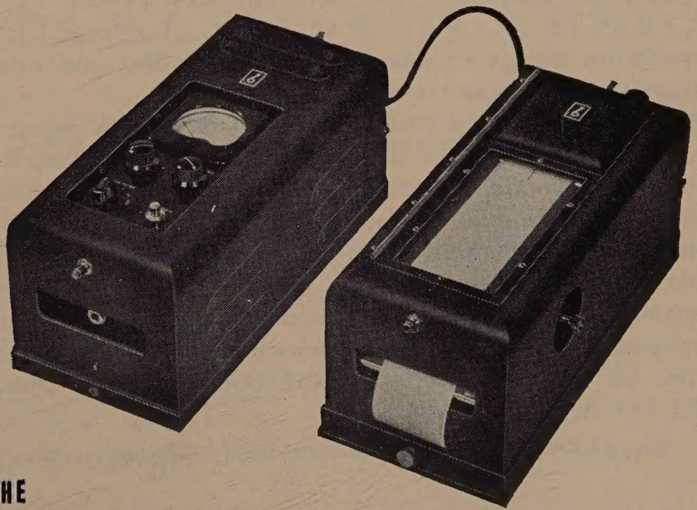

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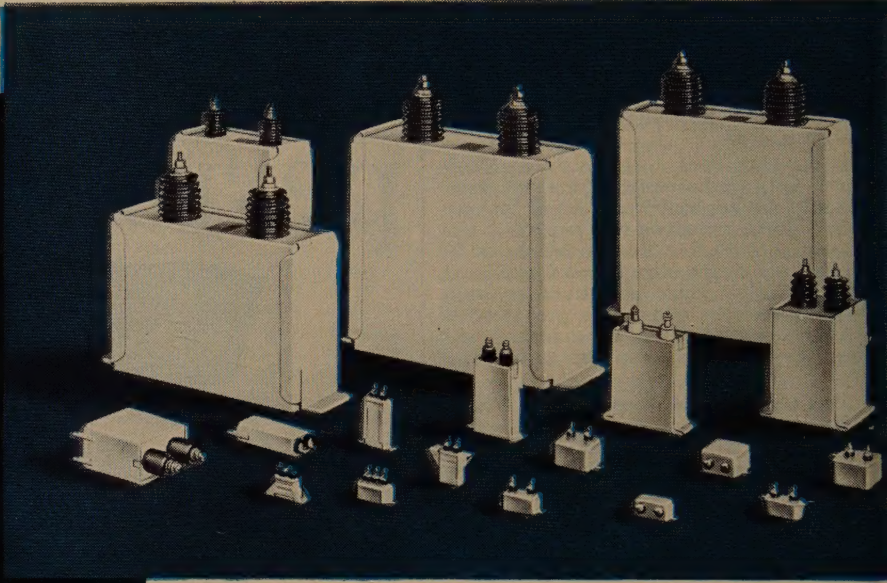


Readily available for DC electronic applications, these capacitors are manufactured in accordance with joint Army-Navy specifications JAN-C-25. Case styles include types CP 53, CP 54, CP 55, CP 61, CP 63, CP 65, CP 67, CP 69 and CP 70. Capacitance ratings are from .01 Muf to 15 Muf, and voltage ratings are listed from 100 to 12,500 volts.

These capacitors are constructed with thin Kraft paper, oil or Pyranol* impregnated, which provides stable characteristics and high dielectric strength. Plates are aluminum foil, manufactured according to detailed specifications. Special bushing construction provides for short internal leads, preventing possible grounds and short circuits. The cases have a permanent hermetic seal to provide longer life. A variety of mounting arrangements are available for various installation requirements. Write for detailed description and operating data: Bulletin GEA-4357A.

*Pyranol is General Electric's non-inflammable liquid dielectric for capacitors.

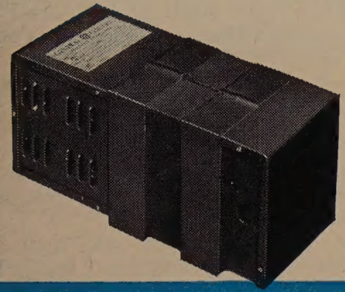
SAVE SPACE CUT COSTS

Less than one inch long, and only one inch square, this postage-stamp-size selenium rectifier offers radio builders substantial savings in production costs. Only two soldering operations and a minimum of hardware are necessary for installation in places where a rectifier tube and socket won't fit. They're built to safely withstand the inverse peak voltages obtained when rectifying (half-wave) 110-125 volts, rms, and feeding a capacitor as required in various radio circuits. Tests prove that selenium rectifiers will outlast the conventional type of rectifier tubes, at the same time costing less. Send for bulletin GEA-5238.

GENERAL ELECTRIC

Digest

TIMELY HIGHLIGHTS ON G-E COMPONENTS

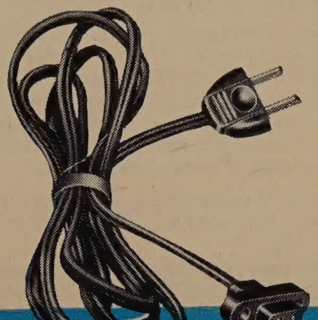


HOLDS OUTPUT VOLTAGE CONSTANT

This 500-va voltage stabilizer is suitable for a wide variety of electronic applications where constant voltage is demanded. Voltage variations from 95 to 130 volts are absorbed almost instantaneously and output voltage maintained at 115 volts (plus or minus 1 percent). There are no moving parts, no adjustments to make. This unit will operate continuously at no load or short circuit without damage to itself. It will limit the short circuit current to approximately twice stabilizer's normal full load current rating. Other sizes available range from 15 to 5000 va. For details, check bulletin GEA-3634B.

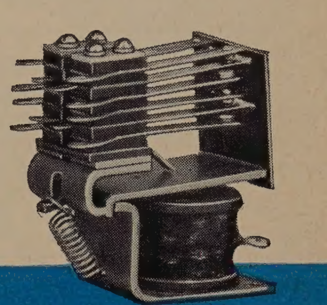
WANT TO TIME TUBE LIFE?

Suitable for installation in radio transmitters, these G-E time meters provide accurate record of tube operating time. They record in hours, tenths of hours, or minutes. Ratings range from 11 to 460 volts. Installation on a panel or switchboard is simplified by quick-wiring leads. Timer harmonizes with other panel instruments in appearance and size. Dependability is assured by Telechron* motor drive. Also available for portable use or conduit and junction box mounting. Check bulletin GEC-472.



FOR YOUR TELEVISION SETS

General Electric's television cord set comes in 6-foot lengths, made of 2/18 Pot-64 brown Flamenol* rip-cord. Set has brown plastic plug and new brown Flamenol connector molded on opposite end. Rip-cord has smooth finish, resists oil, water, acids, alkalies, or sunlight deterioration. Rating is 7 amps., no. 18 wire. Set is designed for assembly on television receiver rear panel, automatically disconnects when panel is removed. Write for further information.



DEPENDABLE CONTROL FOR AUTOMATIC DEVICES

G.E.'s multi-contact relays are inexpensive units built specifically for appliances and vending machines. Construction features assure quiet, reliable operation, and compactness makes them adaptable to a variety of devices such as coin changers, phonographs, and television receivers. Single-circuit contacts or combinations of contacts for multi-circuit application are attached to the same sturdy frame and coil assembly, affording a multiplicity of relay forms. Ratings are 5 amperes at 115 volts or 24 volts, a-c or d-c. Get details from Bulletin GEC-306.

*Trademark Reg. U. S. Pat. Off.

General Electric Company, Section K667-1
Apparatus Department, Schenectady, N. Y.

Please send me the following bulletins:

☐ **GEA-3634B** Voltage Stabilizers
☐ **GEA-4357A** D-C Capacitors
☐ **GEA-5238** Selenium Rectifiers
☐ **GEC-306** Multi-contact Relays
☐ **GEC-472** Tube Timers

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LIBRARY NOTES

ON ARTICLES IN OTHER TECHNICAL JOURNALS

AIR CONDITIONING

Air Conditioning Goes to Work as Manufacturing Tool. *Power*, Feb. 1949; v. 93, pp. 122-125.

Manufacture of precision electronic equipment requires a closely controlled atmosphere. Carefully selected building materials and air-conditioning devices meet this need.

What Will Be the Relative Humidity? by S. P. Goethe. *Refrig. Engng.*, Feb. 1949; v. 57, pp. 140-144, 176, 178.

A method of predicting summer air-conditioning performance at fractional loads is described.

COLOR

Light Sources and Colored Objects, by Ralph M. Evans. *Illum. Engng.*, Jan. 1949; v. 44, pp. 47-54.

Describes the effect of different light sources on colored objects, and the physical principles involved.

Colorimetric Analysis of Dye Mixtures, by David L. MacAdam. *Optical Soc. of Am. Jour.*, Jan. 1949; v. 39, pp. 22-30.

Distributions of chromaticities have been computed for 171 pairs of typical dyes.

COMBUSTION

Computing Combustion Volumes for Burning Oil Fuel, by Ralph Gibbs. *Chem. Engng.*, Jan. 1949; v. 56, pp. 112-115.

Combustion volume for oil fuel depends markedly on degree of atomization, a fact brought out in this new method of computing the volume required.

Time to Discard OLD-FASHIONED WAYS

Jacks . . props . . shores . . horses . . why fool with these obsolete methods of handling reels? DO IT THE MODERN, EFFICIENT WAY! Reel or unreel wire, cable, rope with ROLL-A-REEL

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CORROSION

A Geographic Study of Deposits and Corrosion, by F. N. Alquist. *Corrosion*, Feb. 1949; v. 5, pp. 45-53.

The problem considered in this article is: "How does the composition of water-formed deposits vary among plants located in different geographical areas?"

DIES

Carbide Dies Set Production Records, by A. Earle Glen. *Am. Mach.*, Feb. 10, 1949; v. 93, pp. 85-88.

A million hits per grind is not uncommon with carbide die sets, and life expectancy is reported 20 to 60 times that of steel dies.

ELECTRIC CONTROL SYSTEMS

Contour Controls on a Car-wheel-boring Mill, by W. B. Wigton. *Elec. Mfg.*, Feb. 1949; v. 43, pp. 86-92, 184, 186.

Adaptation of stepping-type relay controls superimposed on magnetic contouring controls for interlocked co-ordinate movements of several tool heads.

Safety in Machine-tool Control, by D. K. Frost. *Elec. Engng.*, Feb. 1949; v. 68, pp. 157-160.

The subject of safety—both of personnel and of the machines themselves—is studied in relation to the ever-increasing use of complex machinery.

ELECTRIC HEATING

Core Baking; 2 Minutes vs 4 Hours, by Victor E. Hillman. *Iron Age*, Feb. 3, 1949; v. 163, pp. 117-121.

The use of an electronic core-baking unit is described.

Heating for Hardening and Forging with R-F Equipment, by Thomas E. Lloyd. *Iron Age*, Feb. 17, 1949; v. 163, pp. 86-92.

Economies resulting from the use of induction heating for heating forging billets and for heat-treating of parts for 100,000 tractors a year.

Versatility of Induction Heating Exploited in Producing Tractor Parts, by J. D. Graham and others. *Steel*, Jan. 31, 1949; v. 124, pp. 62-64, 80.

Use of 6000-kva high-frequency power, ranging from 60 to 450,000 cycles, to induction-heat parts in several manufacturing operations.

FOUNDRY PRACTICE

Antioch Process of Metal Casting, by E. A. Canning. *Foundry*, Feb. 1949; v. 77, pp. 74-77, 230, 232, 234.

Describes a method of casting aluminum automotive parts in molds having gypsum as their basic ingredient.

GAS TURBINES

Designing for Gas-Turbine Materials, by M. H. Young. *Aviation Week*, Mar. 21, 1949; v. 50, pp. 20-22, 24-25.

Stress is no longer the only major consideration. Use of high-temperature alloys introduces new variables. Concerned especially with materials for aviation gas turbines.

LABORATORIES

Radiochemistry Laboratories. *Ind. &* *Engng. Chem.*, Feb. 1949; v. 41, pp. 227- 250.

A collection of eight articles, by differen authors, on the problems peculiar to laboratories handling radioactive substances.

LUBRICATION AND LUBRICANTS

Cutting Oil. *Mill & Factory*, Feb. 1949 v. 44, pp. 137-144.

A special section on practical considerations in their selection and use.

MEASURING INSTRUMENTS

Askania Phototheodolite System, by Thomas H. Bonser. *Tech. Data Digest*, Mar. 15, 1949; v. 14, pp. 15-25.

How phototheodolites are used for photogrammetric surveying of high-speed moving objects in space, especially for determining the flight path of projectiles and the trajectory of bombs and similar bodies.

Counting Rate Meters Versus Scalers, by Arthur G. Bousquet. *Nucleonics*, Feb. 1949; v. 4, pp. 67-76.

Comparison of the advantages and disadvantages of two general types of instruments widely used to determine counting rates of pulses produced by radiation detectors.

REFRIGERATING ENGINEERING

Field Defense Against Moisture, by Howard A. Blair and Richard E. Holmes. *Refrig. Engng.*, Feb. 1949; v. 57, pp. 129-133, 178, 180, 182.

A practical means of combatting moisture in Freon 12 refrigeration systems.

SOLVENTS

Solvent-vapor Control, by John O. Amstuz. *Mech. Engng.*, Feb. 1949; v. 71, pp. 143-147, 149.

A study of the properties and explosion risks of various solvents and their components.

SOUND

Experiment in Stereophonic Sound, by Lorin D. Grignon. *Soc. Motion Pict. Engrs. Jour.*, Mar. 1949; v. 52, pp. 280-292.

An extension of the theory and methods of stereophonic recording and reproduction as particularly applicable to motion pictures.

Objectives for Sound Portrayal, by Ralph K. Potter. *Acoustical Soc. of Am. Jour.*, Jan., 1949; v. 21, pp. 1-5.

Translation of sound into visible patterns is covered in terms of broad objectives. It is suggested that no single design can be optimum and that perhaps the most useful standard of reference is the human ear.

WELDING

English Weld-cracking Test; New Method of Checking High-tensile Steels. *Steel*, Feb. 7, 1949; v. 124, pp. 120, 122, 124, 127.

Description of a method which measures stress across the weld directly, instead of measuring stresses arising out of the thermal expansion and contraction of the test plates.